Feasibility Study:
Tank Blasting Using Recoverable Steel Grit

U.S. DEPARTMENT OF THE NAVY
DAVID TAYLOR RESEARCH CENTER

in cooperation with
National Steel and Shipbuilding Company
San Diego, California

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prepared and submitted by

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San Diego, California

PROJECT *3-89-2*

TABLE OF CONTENTS

TABLES AND FIGURES

Page

TABLES

FIGURES

FOREWORD

This research project was produced for the National Shipbuilding Research Program (NSIW) as a cooperative cost-shared effort between the U.S. Navy and National Steel and Shipbuilding Co. (NASSCO) of San Diego, California. The Surface Preparation and Coatings Panel (SP-3) of SNAME'S Ship Production Committee sponsored the project under the technical direction of Lyn Haumschilt of NASSCO, NSRP Program Manager.

The research was conducted and this final project report was prepared by NASSCO. NASSCO participants included Jerry Keener as Project Manager and Alan Coffer as Project Engineer. H. William Hitzrot of Chesapeake Specialty Products in Baltimore, Maryland supervised the project testing and co-authored the report. Les Hansen, an independent engineering consultant in San Diego, co-authored and edited the final report.

The project team acknowledges Al Hamilton, NASSCO Paint Department Manager, and other members of the Paint Department for their support and cooperation during the project. Appreciation is also extended to the following agencies, shipyards and their representatives for the valuable assistance they provided:

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1. INTRODUCTION

Abrasive blasting of tanks and other enclosed spaces on-board ships comprises a large part of the work effort and budget allocated to surface preparation and coating for both new construction and repair contracts. Traditionally, disposable abrasives such as copper and coal slag have been used for tank blasting, primarily due to familiarity, effectiveness, low initial cost, and relative ease of clean up. However, in recent years shipyards have begun to reevaluate their use of highly friable mineral and slag abrasives in light of economic concerns and recent changes in environmental regulations impacting blast cleaning and disposal of abrasives. Section 5 of this report provides an overview of the regulations affecting abrasive blasting.

Mineral abrasives are commonly used once and then the resulting waste must be transported from the job site for disposal. Due to a high breakdown rate, these abrasives cannot be effectively reused or recycled. This results in large volumes of abrasive waste that must be transported and disposed of in an economical and environmentally compatible manner. Spent abrasive may be considered a hazardous waste, depending on the type of paint removed and the chemical composition of the abrasive itself.

If the abrasive waste does prove to be toxic or hazardous, disposal options become limited and disposal costs can easily exceed the original cost of the abrasive. Waste minimization is mandated under the federal Resource Conservation and Recovery Act (RCRA). As landfills across the country reach capacity and environmental regulations strengthen, the option of landfill disposal for abrasive waste may soon become prohibitively expensive or be eliminated completely.

Another significant factor related to the use of friable abrasives is the amount of dust generated during the blasting operation. Copper and coal slags and other mineral abrasives are known to generate excessive dust due to the rapid breakdown of the grit particles. This “nuisance” dust creates several problems, such as

- Reduced visibility: The dust cloud formed during blasting limits the operator’s ability to clearly see the working surface, resulting in inefficiency and lost time.

- Environmental and respiratory hazard: Although blast operators are required to wear air-supplied breathing apparatus, excessive dust can exceed the permissible exposure limit (PEL) of the protective equipment. Also, airborne dust can be inhaled by nearby workers or passers-by. Uncontained dust also contributes to air pollution.

- Increased operational costs: Excessive dust necessitates larger and more costly dust collection equipment. In addition, dust clings to the newly blasted steel surface, adding to clean-up costs. If not removed, this dust layer can contibute to premature paint failure.

Slag and mineral abrasives are covered under the Navy’s new mil-spec for abrasives, MIL-A-22262A. This specification requires extensive and costly sampling and testing for Type 1, inorganic abrasive. The mil-spec is primarily intended to limit allowable levels of hazardous substances found in abrasives, such as heavy metals and free silica.

The use of recoverable steel grit for tank blasting would appear to reduce or eliminate many of the problems associated with slag and mineral abrasives. Due to the durability and toughness of steel, steel grit can be reused many hundreds of times before individual particles become too small to be effective. As a result, significantly smaller volumes of abrasive waste are generated for disposal. The durability of steel grit also results in very low dust generation, since the particles do not readily break down into fines.

The recovery of steel abrasive through a vacuum recovery system greatly decreases environmental hazards by trapping paint chips and dust, which are segregated from the reusable abrasive. The higher density of steel grit in comparison to other abrasives produces increased cutting ability, while improving worker visibility through decreased dust generation. The increased cutting and low dust equate to increased productivity. Finally, the use of steel grit would not trigger the costly sampling and testing requirements of MIL-A-22262A, since steel abrasive is not covered under this specification.

2. PROJECT OVERVIEW

The primary objective of this project is to investigate and analyze the economic feasibility of using steel grit as a replacement for non-metallic abrasives for tank blasting. Recoverable steel grit can potentially overcome the environmental problems associated with the use of slag or mineral type abrasives. Blasting with steel grit also appears to be more cost effective.

This study will examine the types of equipment available for blasting with and recovering steel grit, as well as the methodology and procedures necessary to effectively utilize the equipment. Information will include the latest state-of-the-art with regard to steel grit blasting. A cost and benefit analysis will be performed to compare steel to slag abrasive in terms of abrasive consumption, productivity , effectiveness, clean up and disposal.

The original intent of the NASSCO project team was to conduct an actual production comparison test of steel and slag abrasives using a Navy vessel being overhauled at NASSCO. However, at the start of this project, steel grit was not fully approved for use aboard Naval vessels. Therefore, a decision was made to perform limited-scope comparison testing of steel and copper slag abrasives using a prototype storage container to simulate a tank environment. (See Section 6 for test description.)

The project approach was divided into five primary tasks as summarized below:

- Survey abrasive reclamation equipment manufacturers and suppliers and develop an equipment comparison list.
- Survey shipyards around the country to determine blasting methods as well as abrasive handling and disposal costs.
- Perform cleaning rate and vacuum recovery tests to compare steel and slag abrasives.
- Develop an economic analysis to compare abrasive consumption, production rates, equipment costs, disposal costs and any other costs that may impact the bottom line of an abrasive blasting project.
- Summarize findings and recommendations in a final report.

This report begins with a discussion of the current methods of tank blasting and the pros and cons of using recyclable steel grit in place of slag or mineral abrasives. The next section provides a summary of the results of surveying shipyards as well as related industries employing recoverable steel grit. (A sample shipyard survey form is included in Appendix A.) An overview of the current environmental regulations and safety issues relative to abrasive blasting is also provided, with particular attention paid to the all-important issue of waste disposal.

Section 6 describes and summarizes the results of the comparison testing that was performed at NASSCO using steel grit and copper slag. These test results form a basis for the economic analysis included in the next section. The economic analysis covers the entire spectrum of abrasive blast-related costs. The report concludes with a summary of recommended procedures for tank blasting with recoverable steel grit, based on input from consultants, survey data and project research. A list of manufacturers of steel grit recycling equipment is included in Appendix B. Appendix C provides a draft of the proposed SSPC specification for steel abrasives. Appendix D shows a sample process control procedure for tank blasting with steel grit.

3. **BLASTING WITH STEEL GRIT VS. OTHER ABRASIVES**

3.1 Tank Blasting Techniques (Current Methods)

Ship tanks such as ballast, fuel, cargo and voids historically have been blast cleaned using various mineral type abrasives. Since many of these tanks are contaminated with oil, salt or other cargo contaminants, using an abrasive blast cleaning material that is used once and discarded meant that there was no concern about contamination resulting from use of recycled abrasive. However, it has been well established in the literature that blast cleaning will not remove contaminants such as oil, grease and salts from the steel substrate. It is necessary, therefore, to thoroughly clean tanks prior to blast cleaning using water blasting and cleaning agents to remove oils, grease and salts from the surface. This has become more important with the advent of sophisticated coating systems and with the use of water based coatings.

The removal of surface contaminants prior to blast cleaning overcomes abrasive contamination, which is one of the major obstacles to the use of recyclable abrasives in tank blasting. With clean tanks, the recycled abrasive will not pick up oils, grease, or salts. Thus the potential for contamination through recycling is removed.

The present method of using single use coal and copper slag mineral abrasives has some major worker safety, environmental and productivity drawbacks, which are briefly outlined below.

- Breakdown - Mineral abrasives and mineral slags in particular tend to disintegrate on impact, generating large volumes of airborne dust. The dust creates a health hazard for blasters and others in the work area, causes poor visibility and reduces the blaster's productivity.

- Material Handling - More abrasive is required, both in volume and in pounds per square foot, to clean with mineral abrasives compared to steel abrasives. This translates into greater handling costs and more complex logistics to continually bring in new material and take away used material.

- Cleaning Efficiency - A recent innovation to abrasive blast cleaning has been the use of higher nozzle pressures, in the range of 120 - 150 psi, resulting in productivity increases of 125- 150% when using steel abrasives. Using mineral abrasives at these elevated nozzle pressures does not dramatically increase productivity because most of the added energy is expended in particle breakdown and increased abrasive consumption.

- Environment - Disposal of the large volumes of potentially hazardous mineral abrasives typically generated by most shipyards is becoming increasingly more difficult and costly, and creates an environmental problem. Generating large volumes of waste is also contrary to the Federal mandate of waste minimization, particularly when there is a viable waste reduction option steel abrasive.

3.2 Advantages and Disadvantages of Recycled Steel Grit

The previous section discussed the current trends using non-recyclable mineral abrasives in tank blasting. This section will outline the major advantages of recycling steel abrasives and will also address some of the often cited reasons that steel abrasives should not be used.

Steel abrasives have two major advantages over alternative abrasives: durability and density. The importance of durability and density in terms of abrasive recyclability is discussed below.

To be truly recyclable, an abrasive must be durable, that is, an abrasive mix must be able to withstand numerous impacts without dramatically altering it's size distribution. Abrasive durability can best be illustrated by comparing a steel abrasive and a mineral abrasive before and after a single use. The data shown below is taken from the project test results, Table 6-B in Section 6.

MINERAL GRIT		STEEL GRIT	
Wt% Coarser than #40 Sieve		Wt% Coarser than #50 Sieve	
Before Blast	After Blast	Before Blast	After Blast
98%	50%	100%	99%

The data above shows that after a single impact mineral abrasive loses almost 50% of its original size compared to steel abrasive, which lost only 1%. Steel abrasives are extremely durable and can be reused hundreds of times without losing size or cleaning ability. Mineral abrasives, on the other hand, if recycled would, after one or two recycles, be too fine and dusty to bean effective abrasive.

The second major attribute of steel abrasive, density, is the key to recyclability. Steel has a specific gravity of 7.4 compared to mineral abrasives which are typically 2.5 to 3.5. Therefore, steel lends itself to simple air classification as a means to remove lighter paint chips, fines and dust from used abrasive. The most common method of air classification is the "air wash" which passes a controlled flow of air through a measured flow of abrasive. The air flow is set such that it will sweep out the paint chips, fines and dust leaving a cleaned steel abrasive product for reuse. Mineral abrasives, on the other hand, have close to the same density as the paint chips, fines and dust contaminating the abrasive. Air washing mineral abrasive is not practical since it will remove almost all the abrasive along with the contaminants.

Maintaining abrasive cleanliness is the key to successful abrasive recycling. Periodic sampling and checking of the recycled abrasive for contaminants such as salt, oil or heavy metals should be incorporated into the production schedule. The Steel Structures Painting Council has a draft specification for recycled steel abrasives. This proposed specification outlines the specific physical and chemical tests that should be run to assure abrasive cleanliness. A copy of the draft specification is included in Appendix C.

Steel abrasives are the ideal recyclable abrasive product based on durability and density. However, there are some precautions to be considered when using steel abrasives. Of primary importance is keeping steel abrasive dry. Steel will rust if allowed to sit in water and with time this rusting can cause the abrasive particles to form lumps which can plug the system. A small amount of moisture is no problem if the abrasive is kept moving and the moisture can then be removed by air dryers in the blasting process.

To summarize, steel abrasives, because of their durability, can be recycled hundreds of times before the particles become too fine for reuse. With recycling, many of the logistical problems encountered with mineral abrasives, such as daily receiving and disposing of truckloads of abrasive are eliminated. Higher nozzle pressures can be used with steel abrasive thus increasing productivity by 125 - 150% while reducing disposal costs by 99%. Steel abrasives offer increased productivity, long life and excellent recyclability compared to mineral abrasives. To realize these advantages, abrasive cleanliness must be maintained along with moisture controls on all compressed air sources.

4. CURRENT INDUSTRY PRACTICE

4.1 Shipyard Survey of Current Methods of Abrasive Blast Cleaning and Recovery

A number of shipyards along the East Coast, Gulf Coast and West Coast were surveyed to determine the procedures being used for tank blasting and some of the problems with current methods. The results of this survey are divided into two areas: new construction and repair. Each of these areas is discussed below. Appendix A shows the format used for the shipyard survey.

New Construction. In new construction most tanks are blast cleaned and painted as subassemblies prior to shipboard erection. With this methodology most yards are blast cleaning subassemblies in large abrasive blast rooms using steel abrasives. This scenario is typical of Bath Iron Works, Newport News Shipyard, Norfolk Naval Shipyard, Ingalls Shipyard and Avondale Shipyard to name a few. NASSCO Shipyard, due to San Diego's favorable climate, is able to perform open-air blasting with steel grit.

All of these yards have found steel abrasive to be the most economical approach to blast cleaning, based on productivity, reduced dusting, waste disposal and ease of recycling. These yards have demonstrated that steel abrasive blast cleaning, recovery, and recycling is a viable and economical approach for shipyards. Although steel is the abrasive of choice for new construction blasting, mineral abrasives are sometimes used for limited field blasting when reclamation and recycling equipment is not available.

Shipyard Repair. Mineral abrasives, particularly copper, coal and nickel slags, are the abrasives of choice for on-board tank blasting. A few yards, such as Puget Sound Naval Shipyard and NASSCO, have begun limited tank blasting with steel grit. Some of the problems associated with the use of steel grit in tanks were discussed in Section 3.

The major deterrents to switching to steel grit have been resistance to change; lack of approved specifications and procedures, particularly for work on Navy ships; maintaining a dry tank environment during blasting; and assuring the cleanliness of the recycled abrasive. The cleanliness problem has been studied and solved by equipment suppliers to the lead paint removal industry. When removing lead paint from steel abrasive, the resultant recycled steel abrasive must meet the cleanliness standards of new abrasive. This topic is covered further in the following section on related industry practice. Appendix B lists available equipment that will meet the cleanliness requirements for effective steel abrasive recycling.

4.2 Steel Grit Usage in Related Industries

Steel abrasives are replacing non-metallic abrasives for maintenance of steel bridges, oil storage tanks and water tanks to name a few. The forces driving this change are the same as those driving the shipbuilding industry, namely

- Waste Minimization
- Worker Safety
- Improved Costs
- Reduced Air Pollution
- Improved Surface Profile and Cleanliness

This trend toward steel abrasives for use in surface preparation for maintenance applications demonstrates the effectiveness of steel abrasives in providing the industry needs cited above.

The removal of lead paint has created a major problem in maintenance of steel structures. During blast cleaning the lead paint contaminates the abrasive, producing a hazardous waste that can only be sent to a hazardous waste landfill. This has increased abrasive disposal costs 100 times from $5.00 to $500.00 per ton and higher. These costs are driving those involved in maintaining steel structures to look at more cost effective methods of blast cleaning.

Steel abrasives have become the abrasive of choice primarily because of their recyclability. Steel abrasives, when used with good containment and recovery methods, can be recycled hundreds of times.

The equipment used has three basic functions: abrasive blasting, recovery and classification (cleaning spent abrasive). These functions can be combined in a single unit or as separate integrated units. When adapting these units to shipyard applications it is important to consider an individual yard's needs and existing equipment. In many cases portions of a yard's existing equipment can be used as part of the abrasive blast, recovery and classification system.

In addition to recyclability, steel abrasives offer some other major advantages over non-metallic abrasives. Steel is two to three times denser than non-metallic abrasives. This high density means that each steel abrasive particle can do two to three times the work of a comparable non-metallic particle, making steel abrasive particles far more effective and significantly increasing cleaning rates.

Because steel abrasives do not breakdown on impact there is virtually no dust generated, so the blaster has improved visibility and is therefore more productive. Since steel abrasives are recycled 100 or more times, the waste generated is only paint and other contaminants removed from the surface. Disposal is reduced from tons per day when using non-metallic to pounds per day with steel.

Surface profile plays a major role in paint consumption. The more profile, the more paint required to provide adequate coating thickness over the peaks. The bridge maintenance industry has found that steel abrasive cleans faster, gives a lower profile and reduces overall paint consumption.

The advantages demonstrated when using steel abrasives in related structural steel applications suggests that similar advantages and savings can be realized when used in shipyards. To realize these advantages, steel abrasive recycling must accomplish the following

- Maximize containment to minimize loss of abrasive

- Maintain a moisture free environment to prevent abrasive from becoming wet

- Provide abrasive recovery and classification equipment that will generate a clean recycled product to be recycled to the blaster

- Use adequate ventilation to assure a safe environment for the blaster

This SP-3 project is verifying much of what has already been learned in related industrial maintenance blast and paint projects. The results of this project are expected to provide the shipbuilding industry with a proven system for more effective tank blasting.

5. OVERVIEW OF CURRENT REGULATIONS

The environmental regulatory requirements pertaining to an abrasive blasting operation are determined by several factors, including job location (state or locality), job size, type of coating removed and composition of abrasive used. Abrasive blasting may be subject to federal and state regulations governing air pollution, water pollution, and the transportation, handling and disposal of hazardous waste. Waste disposal is discussed in Section 5.3. The scope of this section is to provide the reader with a summary overview of the regulatory, as well as health and safety issues surrounding abrasive blasting of tanks aboard ship. Since this discussion is not intended to cover these issues in great detail, each shipyard should ensure that the appropriate personnel become familiar with their local laws and regulations relative to tank blasting.

5.1 Environmental Regulations for Abrasive Blasting

The federal Clean Air Act (CAA), originally enacted in 1955, has been the basis for regulating emissions of air pollutants to protect human health and the environment. The Act has been amended and strengthened several times over the years, most recently with the 1990 Clean Air Act Amendments. Administration and enforcement of the CAA ultimately falls on the Environmental Protection Agency (EPA), however individual states must submit their implementation plans to the EPA for approval. Although the CAA does not specifically regulate abrasive blasting operations, the 1990 Amendments include a provision to control emissions into the atmosphere of fine particulate matter (particle size smaller than 10 microns - "PM 10"). PM 10 is essentially dust, which contributes to the persistent problem of ambient air pollution in some large sties and industrial areas. The PM 10 regulations apply only to areas that currently have a moderate or serious airborne dust problem.

The control of airborne dust as mandated by the CAA would appear to have a potential impact on abrasive blasting operations, particularly for open-air blasting. However, the degree to which blasting contributes to PM 10 pollution has yet to be determined through testing and measurement. The initial results of a recent NSRP project to measure PM 10 emissions during blasting (Ref. 10) indicate that mineral abrasives can generate significant levels of PM 10 dust.

Further research is needed since different abrasive types, used under different conditions, would be expected to generate varying amounts of dust. In particular, slag and mineral abrasives generate significantly more dust than metallic abrasives. Type and age of the coating being removed, or condition of the uncoated surface, will also influence the level of dust generation. In the case of removal of coatings containing toxic elements such as lead, zinc or other heavy metals, dust control and containment become a more critical concern. Stringent limits on airborne emissions of these type of toxics are imposed by the CM Amendments.

The PM 10 regulation will probably not become a major issue for tank blasting. Most tanks are, in effect, enclosed spaces that tend to confine the airborne dust created during blasting. Air exhaust and dust collection equipment is typically used for tank blasting. The use of this equipment improves operator visibility and prevents the escape of most dust through tank openings into the atmosphere. Therefore, the release of PM 10 appears to be a potential factor in tank blasting only if adequate exhaust and dust collection equipment is not used.

While federal environmental legislation does not specifically regulate abrasive blasting operations, some states or localities may. For example, California's Air Resources Board first enacted California Abrasive Blasting Regulations (CABR) in 1974 under the auspices of the Health and Safety Code. These regulations have since been amended several times, most recently in 1990. The primary motivation for the California legislation is control of the respirable dust produced during dry abrasive blasting. In essence, the latest amendments to CABR limit the permissible amount of visible emissions from outdoor blasting operations to a maximum of 40% opacity (Ringlemann 2), which equtes to a 40% reduction in visibility. The Regulations also specify the blasting methods and abrasive types (low dusting) that must be used for blasting "outside of a permanent building: including ship tanks. Steel (or iron) grit is the only abrasive approved for unrestricted outside blasting. Other states may currently have, or may be considering, blasting laws similar to California's.

The Clean Water Act (CWA) of 1977 and the CWA Amendments of 1987, which regulate water quality, may also impact abrasive blasting operations and waste disposal. The CWA regulates quantities of particular hazardous substances or pollutants that may be discharged into surface waters or municipal sewers. One of the primary goals of the CWA is to achieve "zero discharge" of certain pollutants. Therefore, even the smallest discharges of designated pollutants could be subject to regulatory action.

As with the Clean Air Act, the CWA would most likely impact open air blasting operations more than tank blasting. To ensure compliance with the CWA, spent abrasive and paint residue must be prevented from entering surface waters, storm drains or sewer systems. Both the abrasive and paint wastes may contain significant quantities of regulated pollutants. For example, pulverized copper or coal slag, as well as metallic paint dust, may contain high levels of leachable heavy metals such as copper, zinc or nickel. In open air blasting, complete containment of abrasive wastes during operations can be difficult. Precautions need to be taken to keep any fugitive wastes from finding their way into a water source, particularly near bays and estuaries, where toxic sediments are becoming an increasing problem. Tank blasting provides an enclosed space to contain waste debris. Dust collection systems are commonly used to trap airborne fines. Chances are much lower that any of the waste products from tank blasting would end up in a nearby water source.

There is, however, one potential method for abrasive or paint waste to enter waterways as a result of either open air or tank blasting. Following the blast operation, blast waste must be collected and transported to a central storage area in the shipyard to await final disposition according to the yard's current policy for abrasive waste disposal. Care must be taken during this collection, transportation and temporary storage process to ensure that waste products are not accidentally released into or near any water source. Prevention methods include protecting storage areas from the weather, providing secondary containment such as berms, and developing and enforcing comprehensive shipyard "Best Management Practices (BMPs)" relative to waste management. Waste disposal is discussed further in Sections 3.3 and 5.3.

One additional national environmental law has potential to significantly influence abrasive blasting operations. The Resource Conservation and Recovery Act (RCRA), originally adopted in 1976 and revised in 1984, governs all aspects of hazardous waste handling and disposal. The consequences of this law relative to abrasive waste are discussed in Section 5.3.

5.2 Health and Safety Issues

In addition to the state and federal environmental laws and regulations mentioned in the previous section, the State and Federal Occupational Safety and Health Administration (OSHA) regulates abrasive blasting and related activities. Many of the OSHA regulations complement the environmental regulations. In general, the federal and state OSHA regulations pertain to administrative responsibilities including standards-setting, recordkeeping, activities of advisory committees, access to employee medical records, duties of employers, enforcement actions, accreditation of testing laboratories, on-site consultations, and examination and copying of documents.

One of the main health issues associated with abrasive blasting is the respirable dust commonly generated during blasting operations (PM 10, as described in Section 5.1). Dust can be produced either by the breakdown of the abrasive or the removal of the old coating. Both types of dust have potential to contain toxic elements, such as copper or nickel from slag, lead or chromium from old coatings and zinc from newer coatings. Although silica-based abrasives have generalIy been phased out of shipbuilding work, OSHA has established strict limits on worker exposure to silica dust. Silica dust has been associated with the debilitating lung disorder known as silicosis.

An air-purifying respirator with full face piece and hood is the most effective protection from respirable dust available to a blast operator. While this type of protection may be optional for open air blasting, it is normally required in confined areas such as tanks. OSHA has established standards, known as Permissible Exposure Limits (PEL), for worker exposure to many of the toxic substances that may result from abrasive blasting. For example, the eight-hour averaged PEL for lead dust is 50 micrograms per cubic meter.

The OSHA standards permit the concentration of toxic substances in the vicinity of the worker to be reduced through engineering or work practice controls. Engineering controls include the design and installation of an adequate air exhaust and ventilation system in tanks. Where engineering and work practice controls are not feasible or sufficent to reduce worker exposure below the PEL, respirators are required to supplement these controls. A respirator must always be made available to an employee that requests one. Only approved respirators may be used, of a type based on the level of toxic concentration. The employer must also provide a worker training program to include the proper selection, use and maintenance of respirators.

In addition to the lung protection provided by the OSHA PEL limits, skin protection is also required to prevent absorption of toxics. All exposed operator skin surfaces should be covered when concentrations are above the PEL. However, skin protection from toxics is usually not an issue, since blast operators must cover themselves completely and seal all openings to prevent discomfort or injury from rebounding abrasive, particularly in confined spaces such as small tanks.

In situations where hazardous by-products of blasting are known or suspected to be present, worker exposure monitoring is required under OSHA. A preliminary sample of the dust and fines being produced by an abrasive cleaning job can first be analyzed to determine whether hazardous substances are present in significant amounts. If this preliminary testing indicates a potential problem, the operator's breathing zone (outside of protective equipment) should be monitored with a portable collection apparatus. Testing and monitoring should be conducted by a state certified laboratory or a certified industrial hygienist.

Other existing or proposed **OSHA** standards may impact abrasive blasting operations. Shipyard management and personnel involved in these operations should be fully aware of all pertinent standards and requirements. Further information on health and safety issues can be obtained from the state or local OSHA enforcement unit.

5.3 Hazardous Waste Handling and Disposal

Disposal of both hazardous and solid (nonhazardous) waste may be governed by one or more federal laws. The most comprehensive of these laws is the Resource Conservation and Recovery Act (RCRA), originally adopted in 1976. Sweeping amendments to RCRA, known as the Hazardous and Solid Waste Amendments (HSWA), were passed by Congress in 1984. RCRA covers the full spectrum of generation, treatment, storage, handling and disposal of waste. RCRA, in effect, mandates "cradle-to-grave" (i.e., generation to ultimate disposal) responsibility for hazardous waste generators. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, *ALSO* known as Superfund, and the 1986 Superfund Amendments and Re-authorization Act (SARA) may also potentially impact abrasive waste disposal. CERCLA and SARA primarily address the clean up of existing hazardous waste disposal sites and releases or spills of hazardous substances. All federal environmental regulations are administered by the Environmental Protection Agency (EPA).

As previously mentioned, the waste produced during abrasive blasting may be considered hazardous in some cases. The source of the hazardous ingredients could be either the paint removed or the abrasive itself. A sample of the waste products must be tested by a state certified testing laboratory to determine the degree to which the waste is hazardous, if at all. (Testing procedures are described later in this section.) If the waste sample proves to be nonhazardous, several options exist for disposal of the waste.

The most common method for solid waste disposal is in a "Subtitle D" landfill, named for the RCRA section covering nonhazardous solid waste. However, high volume solid waste disposal in municipal landfills is becoming more difficult and costly as landfills reach capacity. With increasing environmental awareness and recognition of the potential for land and water contamination from landfill leachates, many localities are reluctant to approve the opening of new landfills. Therefore, the trend is to establish new landfills further away from urban areas, resulting in higher disposal fees and transportation costs. (See Section 7.3 for a discussion of waste disposal costs.)

The use of recyclable steel abrasive offers significant opportunity to reduce spiraling waste disposal costs. The volume of waste products resulting from the operation of a steel grit recovery and reclamation system is significantly lower than with the use of non-recyclable abrasives. Test results from this project show a 99% reduction in waste using steel abrasive. This reduced waste volume equates to sharply lower disposal fees.

Other options exist as alternatives to landfilling of hazardous and nonhazardous abrasive waste, and these should be explored whenever practical. Alternative uses for spent mineral abrasive include,

- Inclusion of grit waste as an aggregate in concrete or asphalt pavement materials, used to pave highways, roads and airport runways

- As an aggregate additive in the manufacture of various types of bricks for residential and commercial construction

- As an additive to replace fines in the production of Portland cement

A 1990 study performed by Pittsburg Mineral and Environmental Technology, Inc. for the Pennsylvania Department of Transportation (Ref. 11) explored several beneficial reuse options for mineral abrasive waste contaminated with lead. The options included use in Portland cement concrete, asphalt concrete mixes, cement kiln feeds, polishing abrasives, lead smelter feeds and structural clay products. This study concluded that, from both an environmental and economic perspective, the most viable option for the reuse of spent abrasive in Pennsylvania is in clay brick manufacturing. The addition of spent abrasive containing lead actually increased brick strength while reducing manufacturing costs.

Since waste products from a recoverable steel abrasive system consist solely of fines, the use for this waste in some of the applications mentioned above may be limited. Additional alternate uses for abrasive waste may exist or be under development in a particular region of the country. Abrasive manufacturers and suppliers, as well as environmental and waste management companies, are good sources of inquiry for further information.

If sample testing indicates that the waste from an abrasive blasting job is hazardous, disposal becomes a more complicated and costly issue. The handling, transportation and final disposal of hazardous waste are strictly controlled under RCRA. RCRA defines a hazardous waste as any waste that either has been identified or listed by EPA as hazardous, or that exhibits the characteristic of toxicity in excess of established concentration limits. Some abrasive wastes, especially those containing heavy metals, fall under this definition.

The “generator” of the hazardous waste is ultimately responsible for compliance with RCRA regulations. Controversy often exists over the question of who is the waste generator, the shipyard or ship owner. Generally, since the ship owner is specifying the removal of the coating, the owner is considered the generator if the coating is hazardous. However, under certain contractual agreements, the shipyard may take the responsibility of generator, particularly where the abrasive may contain hazardous elements.

Generators of less than 100 kg (220 lb) per month of non-acute hazardous waste are not required to comply with the detailed RCRA regulations, but must assure that their waste is properly disposed of or recycled. A typical tank blasting job using unrecycled mineral or slag abrasives could easily generate tons of waste. However, the amount of waste generated from the same job using steel grit could conceivably be less than the 100 kg limit.

Prior to HSWA in 1984, hazardous abrasive waste was commonly disposed of in a hazardous waste, or “Subtitle C:

landfill. However, HSWA introduced land disposal restrictions that require hazardous waste to be treated prior to disposal to render it nonhazardous. Since no viable treatment method exists for abrasive waste contaminated with heavy metals, a "stabilization" process is used. With stabilization, the hazardous waste is bound into a cement block to prevent toxics from leaching at the disposal site. After stabilization, the waste may be disposed of in a Class C, hazardous landfill. Also, the regulations prohibit dilution of the waste, or residual after treatment of the waste, in order to circumvent the land disposal prohibition. For example, additional abrasive or soil cannot be added to the paint debris in an attempt to create a "non-hazardous" material.

Most shipyards choose to contract with a certified Treatment, Storage and Disposal Facility (TSDF), or a TSDF broker, to remove and arrange for the disposal of their hazardous wastes. Since the generator is ultimately responsible for the waste from "cradle-to-grave," the shipyard must ensure that they are dealing with a reputable hazardous waste hauler or facility. The facility must have all required state and local permits and should not have a history of violations. RCRA requires all TSDFs to have a federal permit to operate their facilities. While the shipyard, as waste generator, is not required to have a federal permit, individual states may require permits for handling or processing waste materials under certain conditions.

The EPA currently endorses one method for testing waste to determine if it is hazardous. This test is the Toxicity Characteristic Leaching Procedure (TCLP), which was designed to simulate long-term leaching that might exist in a sanitary landfill. The TCLP procedure is commonly used to test abrasive waste to determine if stabilization is required prior to land disposal. States may also have testing methods for the analysis of hazardous waste. For example, California's two test methods, Total Threshold Limit Concentration (TTLC) and Soluble Threshold Limit Concentration (STLC), are more stringent than the federal procedure. EPA procedures also specify the size and quantity of samples that must be taken for testing, as well as sampling techniques. Testing should be conducted only by a qualified industrial hygienist or a state approved laboratory.

Due to increased environmental restrictions on hazardous waste disposal, waste management companies are continually exploring new options for waste reduction, reuse or recycling. Most of the options for non-hazardous abrasive waste, mentioned earlier in this section, are also available for hazardous abrasive waste. These include use as an additive in paving materials, brick manufacturing and as a cement additive. However, in some cases the toxic components may exceed RCRA limits, thus restricting the use of the waste. This is particularly true for use in asphalt or concrete paving materials, where toxics could be released as the paved surfaces wear down.

Some states are considering regulatory changes to permit the use of hazardous abrasive wastes in construction and building materials. For example, at the time of this writing, the California Department of Health Services was in the process of finalizing the development of a California regulation covering the use of hazardous waste in asphalt concrete and concrete. This regulation would permit abrasive waste contaminated with moderate levels of heavy metals, such as lead, copper or tin, to be used in the manufacture of asphalt concrete. The final regulation will address several environmental concerns, including

- Potential long-term leachate rates and levels

- Responsibility and liability of the product manufacturers

- Expanded uses in other building products such as clay bricks

- Improved verification and record keeping requirements for manufacturers

- Development of specifications and standards for the manufacture and use of the materials.

The HSWA Amendments to RCRA require all hazardous waste generators to establish waste minimization programs. Generators are required to sign a certification on manifests for off-site shipment stating that they have a program in place to reduce the volume or quantity and toxicity of the waste generated. Generators are also required to submit biannual reports (Form R) describing waste minimization efforts and actual reductions in waste volume and toxicity.

The use of recyclable steel grit as a replacement for non-reusable abrasives would go a long way toward satisfying this waste reduction requirement by significantly reducing the volume of disposable hazardous abrasive waste. However, waste from recyclable steel grit would contain a more concentrated volume of potentially toxic paint particles. The extent to which blasting only tanks with steel grit reduces a shipyard's total volume of abrasive waste depends, of course, on the percentage of tank blasting work as compared to the total blasting work load.

Late in 1992, EPA had proposed modifications to RCRA to establish a new material waste management system. Under this new system, certain wastes now considered hazardous would be downgraded to solid, or nonhazardous wastes, whereas other solid wastes may be designated hazardous. It is unclear if and when these new waste designations will be implemented. This new proposal again underscores the importance for shipyards to remain abreast of changes in environmental regulatory issues.

6. GRIT BLAST AND RECOVERY TESTS

A number of options were looked at when planning the test program. Initially, actual tank blasting aboard a Navy or commercial ship was investigated. However, at the time of the testing, the Navy had not fully approved the used of steel grit aboard Navy vessels. Also, because of the extent of the tests and the length of time required to test the various abrasive mixtures it was decided to conduct the tests on a fixed facility. After looking at several alternatives, a 20 foot long Connex container was selected as a simulated tank configuration. The Connex box chosen had been used for paint storage and had built-in steel shelves. The interior of the Connex box is shown in Figure 6.1, and the overall test set up is shown in Figure 6.2.

Prior to testing, the Connex box was blast cleaned to white metal and repainted with a 3-5 mil coating of Navy Formula 150 Epoxy. The total square footage of the Connex box interior, including shelves, is 1043 square feet. A blast cleaning program was set up based on cleaning the 1043 square foot Connex box and the following data was recorded for each test.

Outline of Data Recorded

Blast Cleaning Test

- Abrasive Consumption
- Nozzle Pressure
- Blast Time
- Abrasive Size Distribution Before and After Blast
- Blast Hose Size
- Nozzle Size
- Surface Cleanliness After Blast
- Square Feet Blast Cleaned

Abrasive Recovery Test

- Type of Vacuum Used
- Vacuum Hose Length
- Recovery Rate
- Size Analyses of Recovered Products

The original test program was designed to determine the advantages of using steel grit compared to mineral grit abrasives. The program was set up as follows:

Standard 600 lb. pots were filled with know weights of abrasive. The interior of the painted Connex box, described above, was blast cleaned completely with mineral grit using air from NASSCO'S compressed air system. The same Connex box, after blasting with mineral grit, was repainted. About four weeks after painting, the Connex box was reblasted completely with G-40 steel grit again using NASSCO'S air system. The same blasters and blast pots were used in both cases to keep the tests as similar as possible.

A decision was made at the conclusion of the mineral and steel grit tests to extend the scope slightly by looking at two key parameters that impact significantly on productivity: nozzle pressure and abrasive particle size distribution. These two tests were conducted using the Connex box and blast cleaning set-up except that a separate compressed air source was used to achieve the higher nozzle pressures. The results of these tests, although somewhat less complete, show that significant improvements in productivity can be accomplished for both mineral and steel abrasives by elevating nozzle pressures. Productivity of steel abrasives can also be increased by using a finer sized abrasive mix.

The test parameters and results are discussed in the following subsections.

Figure 6.1 *Interior of Connex Box.*

Figure 6.2 *Typical Set-Up for the Blast Cleaning Tests. The dedicated compressor is on the left. Blast pot and steel grit drums are in the center. Vacuum recovery and steel grit cleaning station next to the Connex Box on the right.*

6.1 Test Parameters

Table 6-A describes the parameters for the testing. The mineral grit used for the tests is a commercially available copper slag abrasive. The steel grits used for the tests are commercially available steel abrasives. The initial mineral grit and steel grit tests were conducted using yard nozzle air pressure of about 80 psi ± 1.2 psi. For the higher pressure test, a dedicated 1350 cfm compressor and an Ingersol Rand air dryer / after cooler were used to achieve 91 psi k 0.5 psi at the nozzle. The blast hoses used were all 1¼ ID with 10 ft. long, 1 in. ID whip hoses for flexibility. The hose length for the first test was 100 ft. of 1¼ inch hose plus the 10 ft. whip. For the second test, the hose length was 60 ft. including the 10 ft. whip.

The same 600 lb. blast pots were used for all tests. The pots were weighed empty and the weight recorded. The pots were then filled with abrasive and re-weighed. This filled weight less the tare weight of the pot gave the weight of abrasive. At the conclusion of the test the pot was re-weighed, the weight of the pot subtracted from this weight giving the amount of abrasive still in the pot. This weigh-in weigh-out method enabled an accurate determination of abrasive consumption for each test.

The area blast cleaned was the interior of a Connex box as described earlier and shown in Figure 6.1. After each blast cleaning test the Connex box was repainted with approximately 3 -5 roils of epoxy. The coating was allowed to dry for three to four weeks before being reblasted.

TABLE 6-A
TEST PARAMETERS

	TEST 1 (LOW PRESSURE)		TEST 2 (HIGH PRESSURE)	
TEST PARAMETER	COPPER SLAG	STEEL GRIT G-40	COPPER SLAG	STEEL GRIT G-40/50
Nozzle Pressure	80 psi	80 psi	90 psi	90 psi
Supply Pressure (psi)	100	100	120	120
Hose Length (Pres. Pot to Nozzle)	110ft	60 ft	60 ft	60 ft
Nozzle Size	#7	#7	#7	#7
Coating Thickness (Prior to Blast)	2 mils	2-3 mils	2-3 mils	2-3 roils
Type Blast Equipment	600 lb.		600 lb.	
Area to be Blasted	Connex box 1043 Sq. ft.		Connex box 1043 Sq. ft.	
Vacuum Type	Liquid Ring, 75 hp		IR AirVac	
Vacuum Recovery Hose	120 ft.		120 ft.	
Vacuum Head	12" Hg	11.2 Hg	15" -18" Hg	

Vacuum recovery was tested at the completion of each blast cleaning test. The initial vacuum recovery for the mineral grit and steel grit tests were done using NASSCOS water-vat recovery systems. Vacuum recovery after the higher pressure -90 psi-test was conducted using an IPEC air-vat vacuum recovery system. The vacuum recovery results are discussed under Section 6.4.

6.2 Screen Analysis Results

Table 6-B summarizes the size analyses of all abrasive products tested before and after blast cleaning. The sieve sizes used for the screen analyses are the manufacturers recommended sizes for the products used. It should be noted that the new slag and steel abrasives have significantly different size distributions. Copper slag, because of its lower density, is significantly coarser that steel grit. 70% of the slag is coarser than a #18 screen compared to only 2% of G-40 steel grit. Finer slag particles — particles finer than a #40 sieve — have little cleaning value and end up as dust. Steel grit, on the other hand, because of its density and durability, is an effective abrasive even at #50 sieve size. Because of the inherent differences in the two abrasives, common industry practice sets the minimum effective size for the copper slag at #40 sieve and for G-40 steel grit at #50 sieve. For slag, particles finer than #40 sieve are considered too fine for blast cleaning. For G-40 steel grit, the minimum size is #50.

Comparing the breakdown of slag abrasive versus steel abrasives in Table 6-B, it is clear that slag abrasives lose a significant amount — almost 50% — of their particle size after a single use. This disintegration manifests itself in excessive dust generation, as shown in Figure 6.3. This photo was taken during the copper slag blast cleaning test. Compare Figure 6.3 with Figure 6.4, which was taken during the steel grit blast cycle. Little or no dust was generated, and in contrast to the slag test, the blasters used no lighting.

Analysis of steel grit after the blast test showed that steel abrasive breakdown at 80 psi was about 1% after initial impact. Compare the size analysis (Table 6-B) of steel grit before and after blast, at weight percent coarser than #50 sieve. Steel grit is 99% recyclable after one use and still 99% recyclable after two (2) uses. This demonstrated durability of steel coupled with the significantly lower dust levels illustrates the advantages of steel compared to slag abrasive.

Blast cleaning efficiency is a function of the amount of energy transmitted by the abrasive particle to the steel surface. A major portion of the energy of a mineral abrasive particle is expended in abrasive particle breakdown (50% size reduction on impact) rather than cleaning the steel substrate. Steel, on the other hand, shows that 99% of the energy is imparted to the steel substrate (1% size reduction on impact). Steel's more efficient use of energy is apparent in the productivity results shown in Table 6-C.

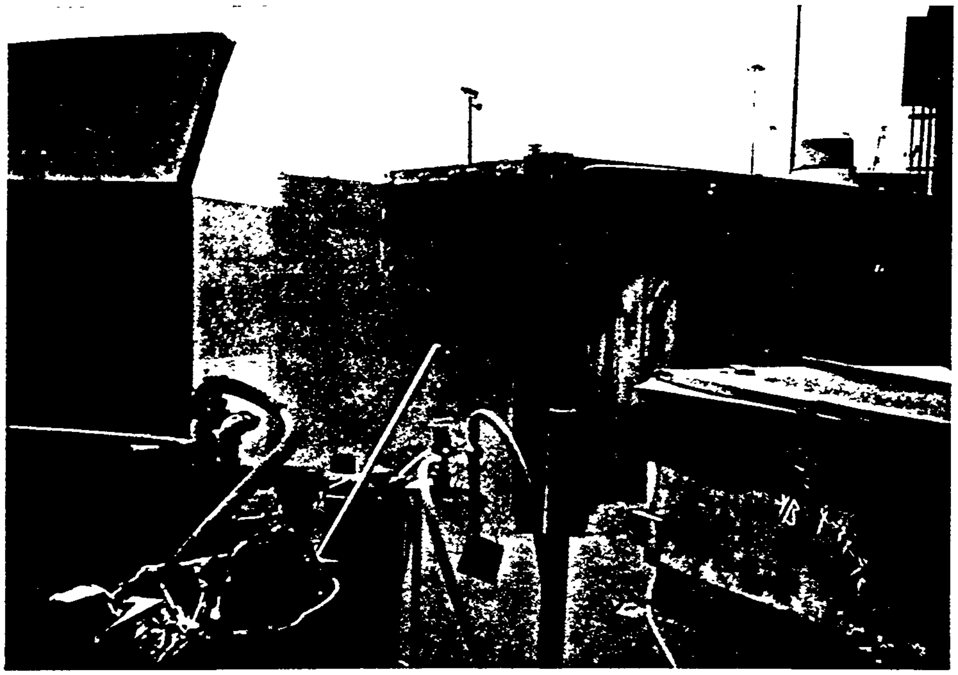


Figure 6.3 *Dusty Blast Cleaning Environment when using Mineral Abrasive.*

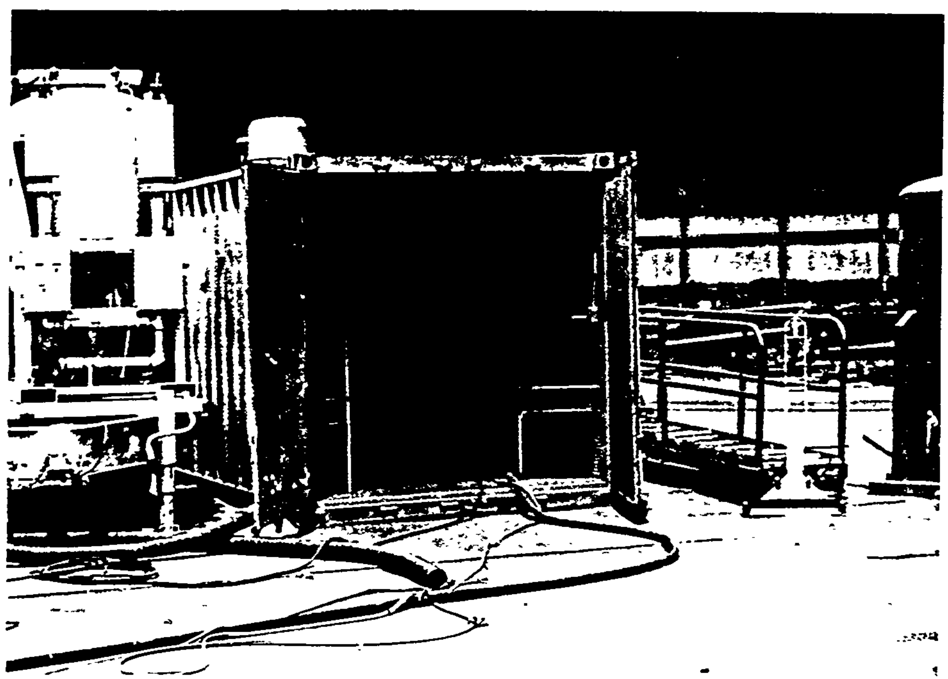


Figure 6.4 *Blast Cleaning with Steel Grit. Note low level of dust and excellent visibility well within the Connex Box.*

TABLE 6-B
SCREEN ANALYSIS RESULTS

MINERAL GRIT, 80 PSI

SIEVE SIZES	SIEVE OPENING, IN.	NEW CUMULATIVE WT.% RETAINED	USED (1st USE) CUMULATIVE WT.% RETAINED
12	.066	6	1
16	.047	45	4
20	.033	72	13
30	.023	90	28
40	.017	98	50
70	.008	99	83
Pan		100	100

G.40 STEEL GRIT, 80 PSI

SIEVE SIZES	SIEVE OPENING, IN.	NEW CUMULATIVE WT.% RETAINED	USED (1st USE) CUMULATIVE WT.% RETAINED	USED (2nd USE) CUMULATIVE WT.% RETAINED
18	.039	2	2	1
25	.028	36	27	22
30	.023	75	59	59
40	.017	99	94	94
50	.012	100	99	99
Pan		100	100	100

G-40/50 BLEND STEEL GRIT, 90 PSI

SIEVE SIZES	SIEVE OPENING, IN.	NEW CUMULATIVE WT.% RETAINED	USED (1st USE) CUMULATIVE WT.% RETAINED
20	.033	6	6
25	.028	22	22
30	.023	48	42
40	.017	92	82
50	.012	99	98
Pan		100	100

Screen analyses were also run on the abrasives used at the elevated nozzle pressure and the finer sized steel abrasives. These analyses are included in Table 6-B. It is interesting to note that the finer G-40/G-50 blend steel abrasive showed very little breakdown on impact at the higher nozzle pressure of 90 psi (1% breakdown going from 99% coarser than #50 sieve for new abrasive to 98% after one use). This demonstrates that even the finer G-50 steel grit particles are tough, do not break down and are recyclable.

In addition to the recycled steel abrasive product, the fines generated by the reclaiming system were also examined. These results showed that only trace amounts of usable steel abrasive were pulled out by the reclaiming system. The bulk of the fines generated by steel grit blast cleaning were made up of the coating system removed from the Connex box.

No attempt was made to analyze the abrasives or residues for salt, oil, or other contaminants. The interior of the Connex box had not been exposed to any traceable contaminant that would make such analyses meaningful. Contamination of recyclable abrasive is an important and controversial issue and should be included in any future research.

6.3 Test Results

Table 6-C summarizes the data collected during the test phase of the program. The primary objective was to compare the

TABLE 6-C
MINERAL GRIT VS. STEEL GRIT TEST RESULTS

TEST PARAMETER	COPPER SLAG	STEEL GRIT G-40
Nozzle Pressure	80 psi	80 pSi
Total Area Cleaned (square foot)	1043	1043
Total Cleaning Time (hours)	5.94	2.85
Total Amount of Abrasive Applied (pounds)	7940	7020
Volume Abrasive Applied (cubic foot)	69	26
Rate Abrasive Applied (pounds/square foot)	7.6	6.7
Rate of Cleaning (square foot/hour)	176	366
Consumption (pounds/square foot non-reusable abrasive)	7.6	0.1
Recovery Factor (Percent Reusable Grit After Blast)	0	99
Profile*(mils)	4.2	4.1
Degree of Cleanliness	SP1O	SP5

•the high profile produced by the initial mineral grit abrasive will not be significantly reduced by subsequent abrasive blasts. Thus the Testex profile results were all about the same.

cleaning rates of steel abrasive and mineral abrasive under essentially similar conditions. Cost analyses based on the test results are discussed in Section 7. It should be emphasized that these test results are based on removing a 3-5 roil, one-coat coating system; an easy job which would account for the excellent cleaning rates achieved. Production rates achieved during this test may not reflect rates for actual field work, and should be used for comparison of abrasives only.

The test results show some significant productivity differences. For example, it took more than twice as long, 5.94 hours, to clean the same area using copper slag compared to the 2.85 hours needed when using steel grit. These same numbers show up in the cleaning rate, with slag cleaning at a rate of 176 square feet per hour versus steel grit at 366 square feet per hour. The actual degree of cleanliness after blast was not the same. The sIag abrasive achieved an SP 10 (near white) compared to steel grit's SP 5 (white metal). In discussing this cleanliness difference and cleaning rate difference with the blasters, they said visibility was a problem because of the dust generated by the slag making it difficult during blasting to determine the degree of cleanliness achieved. Also, copper slag left a residue on the surface, confusing the degree of cleanliness.

Another significant difference between mineral abrasives and steel abrasives is the amount of abrasive applied. Compare in Table 6-C the slag and steel grit tests at 80 psi. The results show that about 7,900 pounds of slag and about 7,000 pounds of steel grit were used to blast clean the same area. However, if we look at the volume of material used there is a significant difference. Copper slag required 69 cubic feet of grit compared to only 26 cubic feet of steel grit. Steel grit, due to its higher density, offers a 62% reduction in the volume of grit that must be handled.

Since blast cleaning is essentially a material handling operation, anything that reduces the volume of material that must be handled will significantly reduce the cost of the operation. Steel abrasive requires a little over 1/3 the volume of material compared to copper slag. Every cubic foot of material brought into the job must be picked up and removed, thus clean-up of steel grit with about ²/3 less volume, will be faster and less costly. Clean up costs are further discussed in Section 7.2.

A final important difference between slag and steel grit is abrasive consumption per square foot; that is, the amount of non-reusable abrasive after each use. Since copper slag is not normally reused, the 7.6 pounds per square foot used for blast cleaning must be picked up and disposed of. Compare this to steel abrasive which had 0.1 pounds of waste per square foot blast cleaned for disposal. The waste for steel is calculated by multiplying the abrasive application rate of 6.7 lbs/ft^2& (from Table 6-C) by the 1% loss per cycle (from Table 6-B). The result is 0.067, which is rounded to 0.1 lb/ft^2.

Steel grit offers a 99+% reduction in waste per square foot blast cleaned compared to copper slag. An earlier MARAD study done in 1987 (Ref. 9) looked at recycling mineral abrasives. The study proved the feasibility of limited recycling, but as yet no shipyard has implemented the process. A more recent study by Pittsburgh Mineral and Environmental Technology, Inc. (Ref. 11) attempted to demonstrate the recyclability of mineral abrasives. The results of this study indicated that about 40% of first-use spent mineral abrasive could be reused one additional time. With such limited reuse potential, the cost effectiveness of mineral grit recycling appears marginal at best. Steel grit currently offers the most economical and productive solution to the regulatory mandate for waste minimization.

Since steel grit will be recycled, we looked at the recovered steel abrasive to see how much change in size took place after one and two bIast cleaning cycles. Table 6-B

TABLE 6-D
ELEVATED NOZZLE PRESSURE AND BLENDED ABRASIVE TEST RESULTS

TEST PARAMETER	COPPER SLAG	STEEL GRIT G-40/G-50 BLEND
Nozzle Pressure	90 psi	*90* psi
Total Area Cleaned (square foot)	55	377
Total Cleaning Time (hours)	0.18	0.66
Total Amount of Abrasive Applied (pounds)	640	1583
Rate Abrasive Applied (pounds/square foot)	11.6	4.2
Rate of Cleaning (square foothour)	305	628
Consumption (pounds/square foot non-reusable abrasive)	11.6	0.05
Recovery Factor (Percent Reusable Grit After Blast)	0	99.9
Profile* (mils)	4.5	4.3
Degree of Cleanliness	SP10	SP5

• The high profile produced by the initial mineral grit abrasive will not be significantly reduced by subsequent abrasive blasts. Thus the Testex profile results were all about the same.

shows the screen sizes after each of these blast cycles. Note that there is very little size change and that 99% of the abrasive is recoverable for reuse.

In addition to the comparison of mineral grit and steel grit, tests were run to evaluate other parameters that affect blast cleaning. One test looked at the effect of elevated nozzle pressures and the other test looked at working mix particle size. These tests were initiated because many painting contractors doing blast cleaning and painting of structural steel have found that blast cleaning at nozzle pressures of 120 - 130 psi have resulted in marked increases in productivity. In addition, when using these elevated nozzle pressures, contractors have found that a finer abrasive working mix further enhances productivity.

Table 6-D summarizes the test results using higher nozzle pressures and using a blended steel abrasive media. These tests were conducted to demonstrate the effect of nozzle pressure and particle size on cleaning properties. A more complete study should be made to optimize the benefits. These preliminary results are discussed in more detail below.

Nozzle Pressure

Initially, a significantly larger difference in nozzle pressure was planned, but because of equipment problems only a 10 psi difference was achievable. However, even with this small increase in nozzle pressure there was about a 70% increase in cleaning rate for both the slag and steel abrasives. Compare Rate of Cleaning in Table 6-C with Rate of Cleaning in Table 6-D. This demonstrates dramatically that elevating nozzle pressure can make a significant improvement in productivity . The results are still significant even when considering that some of this increase may have been the result of the small areas being cleaned or blaster technique as the blaster became more familiar with blast cleaning the Connex box.

Working Mix Particle Size

These results are also summarized in Table 6-D. Compare the amount of abrasive applied per square foot with straight G-40 (see Table 6-C), 6.7 pounds versus 4.2 pounds for G-40/G50 blend (see Table 6-D). By going to a finer particle size and elevating nozzle pressure there was a 37% reduction in the amount of abrasive used to clean each square foot. This marked improvement in abrasive consumption can be explained by the increased coverage resulting from the finer particle size (G-50 grit) introduced into the G-40 grit.

The advantages demonstrated by these two tests emphasize the need for a more complete study of nozzle pressure, abrasive particle size and their relationship to cleaning rate. These were demonstration tests to examine other parameters impacting blast cleaning and involved cleaning relatively small areas, 55 square feet for mineral grit and 377 square feet for the steel grit blend. Limits on project time prevented a more complete study. A follow-up study should include blast cleaning significantly larger areas to more adequately demonstrate the effect of nozzle pressure and abrasive particle size. This follow-up study would be included in the proposed Phase II of this project.

It was hoped that this project would provide an opportunity to evaluate abrasive cleanliness. Unfortunately, because of the type of coating system used on the Connex box there was no heavy metal element that would be easily traceable in the reclaimed abrasive. A heavy metal could be detected analytically if it had been picked up by the steel grit. Sieve analyses on the cleaned, recycled abrasive (see Section 6.2) showed less than 1% minus #50 sieve (0.0177”) material in the cleaned abrasive mix, indicating that the abrasive cleaning station was removing the dust and fines horn the abrasive. In addition, the fines that remained in the recycled abrasive were essentially finer metallic abrasive particles, not paint chips. For future tests, a test cycle should be run that would allow 5-10 recycles to fully evaluate abrasive cleanliness in terms of paint, oil, grease, salt, and other potential contaminants.

6.4 Vacuum Recovery

Abrasive recovery, whether for recycling or just abrasive removal after blast cleaning, is a major labor cost when blast cleaning. This study looked at vacuum recovery rates for both mineral abrasive and steel grit abrasive. Extensive vacuum recovery tests were not run because of the short blast cleaning cycles. However, these limited-scope tests demonstrated the following

- Vacuum recovery of steel abrasives can be accomplished with the same equipment used for mineral grit abrasive.
- Vacuum recovery time is more sensitive to volume than to density of the abrasive media.
- Blow-down after blast and recovery takes almost twice as long with copper slag as with steel grit.

The parameters for the vacuum recovery tests are summarized in Table 6-E. The same 75 hp liquid ring CAB vacuum recovery unit was used for both tests. No problem was experienced in vacuuming steel grit even though it is almost three times heavier than copper slag abrasive. The major difference in vacuum recovery between slag and steel abrasives was in the time required to clean up the spent abrasive. Almost three times as much slag by volume was needed to clean the test areas as compared to steel grit. This resulted in approximately 40% longer vacuum clean up time for the slag.

An additional difference noted was in blow-down time after blasting and recovery. The excessive dust generated by mineral grit required almost twice as long to blow-down the blasted surface compared to steel. These preliminary recovery trials show a potential labor cost savings on cleanup and recovery of about 33% when switching from mineral grit to steel grit. Section 7.2 further discusses recovery and clean up costs.

TABLE 6-E
VACUUM RECOVERY TEST
(After 80 psi Blast Test)

TEST PARAMETER	MINERAL GRIT	STEEL GRIT
Type Equipment	Liquid Ring, 75 hp	Liquid Ring, 75 hp
Vac Hose Length	120 ft.	120 ft.
Recovery Rate	2600 lbs/hr	3240 lbs/hr
Clean Up Time	3.1 hours*	2.2 hours**
Vacuum Head (inches Hg)	12 in.	11½ in.
Blow-down Time (after blast and recovery)	30 minutes	17 minutes

* Pounds of abrasive applied (Table 6-C) = 7940 lbs. / Recovery Rate (Table 6-E) = 2600 lbs./hr =3.1 hours

** Pounds of abrasive applied (Table 6-C) = 7020 lbs. / Recovery Rate (Table 6-E) =3240 lbs./hr =2.2 hours

7. ECONOMIC ANALYSIS

This section addresses the economics of tank blasting with recyclable steel grit as compared to commonly used disposable abrasives. Copper slag was chosen as a representative disposable abrasive, although other types of slag and mineral abrasive are also used around the country. Cost and performance of most of these non-metallic abrasives, when compared to steel, will not vary significantly. If desired, cost data for other abrasive types can be substituted for copper slag in any of the analyses in this section to make the comparisons more meaningful for a particular shipyard.

The cost comparisons in this section are primarily based on the project test results as discussed in the previous section. As mentioned, the scope of the testing was limited since actual on-board production testing could not be arranged. Therefore, the data collected during the simulated tank test is considered to be somewhat limited, but still representative of a production situation.

Table 7-A summarizes the cost data obtained by analyzing the test results. The cost categories are then discussed in more detail in this section. To allow meaningful comparisons, all cost values are given in dollars per square foot of area cleaned. A comparison of the total cost per square foot at 80 psi indicates that steel abrasive costs are about one half the costs using copper slag.

Using the data from Table 7-A, overall costs can be projected for a typical shipboard tank blasting job. The total surface area for a small tank (40’ x 20’ x 20’) would be about 5000 &, including a 30% allowance for stiffeners and other structural members. A typical large tank (60’ x 40’ x 40’) would contain about 16,000 &. Projected total job costs for these tanks, including material, labor, waste disposal and recycling costs, are shown in Table 7-B.

TABLE 7-A
COST SUMMARY FROM TEST RESULTS

Note: **Cost Values Shown** are in Dollars per Square Foot Blast Cleaned

COST CATEGORY	MINERAL GRIT 80 PSI	STEEL GRIT (G+40) 80 PSI
Abrasive Cost	0.26	0.025
Blast Cleaning Labor Cost	0.20	0.10
Vacuum Recovery Labor Cost*	0.124	0.086
Disposal Cost	0.19	0.003
Recycling Cost	0	0.17
Total Cost per SquareFoot Blast Cleaned	0.774	0.384

* includes blow-down time

The following assumptions were made to develop this cost summary:
- Labor at $36/hour including fringes
- Average abrasive landfill disposal at $50 per ton including hauling
- Cost per ton of abrasives (all prices FOB NASSCO):
  - Copper Slag-$ 69 per ton
  - G-40 Grit-$500 per ton

7.1. Abrasive Costs

The abrasive cost information discussed below is taken from the project test data. For comparison and additional information, a cost analysis of steel grit and slag abrasives, provided by the IPEC Company of Rhode Island, is also included as Table 7-C. This analysis indicates that the typical annual cost of using slag abrasive is about seven times higher than the cost of using recycled steel grit.

The test results in Table 6-C (80 psi test) show that approximately equal weights of steel and slag abrasives were used during the test. However, due to the much higher density of steel (2.5 to 1), the volume of steel abrasive used is about one third the slag volume. Also, steel grit is applied at a lesser rate (6.7 lbs/ft^2) than the slag (7.6 lbs/ft^2), so steel gains an advantage from the start. The obvious major advantage in material cost with steel grit is reusability. Although typical steel abrasive cost is nearly seven times higher than slag, when recyclability is factored in, the steel cost drops to a fraction of the slag cost.

Table 7-A shows the slag and steel abrasive costs per square foot blasted to be \$0.26 and \$0.025 respectively. The costs are calculated as follows (using data from Table 6-C):

7.6 lb/ft^2 (Consumption Rate) x \$69/ton (Slag Cost) ÷ 2000 lb/ton = <u>\$0.26/ft^2</u>

Steel grit cost per square foot blasted

0.1 lb/ft^2 (Consumption Rate) x \$500/ton (Steel Grit Cost) ÷ 2000 lb/ton = <u>\$0.025/ft^2</u>

This comparison shows that, based on test data, the cost of actual material consumed for steel abrasive is about one tenth of the copper slag cost. Total abrasive costs for the test area are

SLAG:
1043 ft^2 x \$0.26/ft^2 <u>\$271.18</u>

STEEL GRIT
1043 ft^2 x \$0.025/ft^2 <u>\$26.08</u>

7.2 Recovery and Clean-Up Costs

Recovering and cleaning up spent abrasive contributes a significant cost to the abrasive blasting operation. In many cases, the labor cost involved in cleaning up spent abrasive exceeds the labor cost of applying the abrasive. This is true regardless of the type of abrasive used, although costs can vary depending on abrasive type and recovery method.

TABLE 7-B
PROJECTED TANK BLASTING COSTS

	SMALL TANK			LARGE TANK		
	AREA, FT^2	COST/FT^2, \$	TOTAL COST, \$	AREA, FT^2	COST/FT^2, \$	TOTAL COST, \$
COPPER SLAG	5,000	0.774	3,870.00	16,000	0.774	12,384.00
STEEL GRIT	5.000	0.384	1,920.00	16,000	0.384	6,144.00

TABLE 7-C
COST COMPARISON
STEEL GRIT VS. SLAG ABRASIVE

This analysis is based on the following:

Number of Blast Nozzles	1
Nozzle Size	1/2"
Blasting Pressure (nozzle)	100 psi
Air Consumption	300 cfm

Abrasives Appaer Hour

Slag	1,500 pounds @ $ 50.00/ton
Steel Grit	3,500 pounds @ $450.00/ton

Non-Recycled Slag vs. Steel Grit

Calculating abrasive costs per year and assuming six manhours (M. H.) per day and 250 blasting days per year

6 hrs, x 250 days = 1,500 manhours of blasting per year per operator

For slag abrasive, the yearly consumption is calculated as follows:

1,500 ibs/M.H. x 1,500 M.H. = 2,250,000 ibs. per operator per year, or

$\frac{\text{2,250,000 ibs}}{\text{2,000 ibs/ton}}$ = a yearly consumption of 1,125 tons of slag per operator

For steel abrasive, the yearly consumption is calculated as follows:

3,500 Ibs/hr. x 1,500 hrs. per year= 5,250,000 ibs. per operator per year.

$\frac{\text{5,250,000 ibs}}{\text{2,000 ibs/ton}}$ = 2,625 tons of steel grit per year

if properly utilized however, steel grit can be recycled up to 150 times (cycles), thus:

$\frac{\text{2,625 tons}}{\text{150 cycles}}$ = a yearly consumption of 17.5 tons of steel grit per operator.

Material Cost per year for slag would be:

1,125 tons/yr. x $50/ton =$56,250.00 per operator

Cost of steel grit for actual consumption would be:

17.5 tons/yr. x $450/ton =$7875 per operator

Data supplied by IPEC Co.

Vacuum recovery is the most common method for spent abrasive collection. The primary vacuum types are liquid ring and air induction and positive displacement (PD) pumps. Liquid ring vacuums use centrifugal water flow to generate a vacuum head, while air induction and PD systems generate negative air pressure to produce a vacuum.

With mineral or slag abrasives, blasting and waste clean-up are separate operations using separate equipment. Spent abrasive is usually collected in storage hoppers and eventually sent out of the shipyard for disposal or reprocessing. Steel grit recovery systems, however, are complete, closed systems in which spent abrasive is vacuumed, cleaned, reclassified and stored for reuse. The small amount of unusable waste generated (dust and fines) is collected for disposal.

The costs associated with operating the recycling equipment required for a steel grit system must be included in the overall cost comparison of steel and mineral abrasives. These costs do not occur for mineral abrasives, since they are normally not recycled. The cost summary in Table 7-A indicates a recycling cost of $0.17 per square foot, which is determined as follows:

6.7 lb/ft² (Application Rate) ÷
2000 lb/ton x $50/ton (Recycling Cost) +
0.99 (Recovery Factor) = **$0.17/ft²**

The Application Rate and Recovery Factor used above are taken from Table 6-C, Test Results. The Recycling Cost represents a typical average cost including labor, operation, and maintenance expenses for recycling equipment.

Abrasive blasting in tanks often results in increased recovery and clean-up costs due to accessibility problems. Tank access is commonly available only through an opening in the tank top. Vacuum hose must then be run from the equipment location on deck to the bottom of the tank — often over 100 feet. To minimize flow resistance, large diameter vacuum hoses (3-6" I.D.) are normlly used. If possible, a temporary access opening can be cut near the bottom of the tank to allow easier grit removal. Mechanical methods, such as a screw conveyor, may also be used to more effiaently remove steel grit.

The results of the vacuum recovery test performed in this project (see Table 6-E) show that the spent abrasive clean up time for copper slag was 3.1 hours as compared to 2.2 hours for steel grit. Recovery and clean up labor costs are discussed in Section 7.5 Labor Costs. The difference in clean up time indicates a savings of about 30% when using steel grit. However, since this test was not performed in a tank on-board a ship, the results must be taken at face value for the test conditions. Conclusions cannot be drawn for actual on-board applications based on this test data, as conditions and costs may be different in tanks.

Steel grit does have a distinct advantage over other abrasives in the clean-up process. Slag and mineral abrasives produce large amounts of dust during blasting. This dust normally adheres to all exposed tank surfaces, such as bulkheads, stiffeners and overheads. Dust must be removed prior to painting to prevent potential coating failure. Removal of dust by brushing, sweeping or blowing down with air is labor intensive, especially in complex tanks. Since steel grit produces significantly less dust than other abrasives, dust clean-up time is reduced and cost savings are realized.

Dust blow-down time was measured during the NASSCO test as shown in Table 6-E. The time for blow-down after blasting with copper slag was about twice as long (30 minutes) as the time for steel grit (17 minutes). While this difference might seem insignificant for a small test area, the savings with steel grit would be substantial for a typical tank cleaning job.

7.3 Waste Disposal Costs

Abrasive waste disposal costs can have a significant impact on the total job cost, particularly if the waste proves to be hazardous. (See Section 5.3 for a discussion of hazardous waste disposal.) Disposal costs will vary based on the method of disposal. Probably the most expensive method currently is landfill disposal. For example, the southern California 1992 fees for solid, non-hazardous (Class 2 or D) grit waste disposal were $65/ton plus a 10% local surcharge. Typical hauling charges can add $25/ton, resulting in a total cost of about $100/ton.

If the grit waste tests hazardous (Class 1 or C), landfill fees increase to $85/ton and the total cost becomes nearly $125/ton. Thus, landfill disposal costs in California can amount to almost double the raw material cost of slag abrasives. Fees for landfill disposal will vary by state and locality. Also, landfill disposal will become a limited and more expensive option for many states in the future as current disposal sites fill and new sites are not readily available.

Alternative methods to landfill disposal, such as those discussed in Section 5.3, can result in greatly reduced grit waste disposal costs. In some cases, manufacturers of building materials such as concrete, asphalt or bricks will buy (at a small price) spent abrasive from shipyards to use in their products. Most commonly the shipyard pays a nominal fee ($20 - 30/ton) to have the waste hauled to the manufacturer's facility.

In California, grit waste is also being used as a cement additive. Fees to haul the waste to a state approved cement kiln run $20-30/ton, plus a processing fee of about $20/ton. Alternative methods of waste disposal, where available, are becoming more popular as a way to lower disposal costs and reduce the landfill overcrowding problem.

A comparison between potential waste disposal costs for slag and steel abrasives can be made based on the project test results. Table 6-C data shows that, since slag is not recycled, all of the 7940 lbs. used during the test has to be disposed of. For the steel grit, approximately 100 lbs. of waste residue was left in the dust collection drum after the test. All other material was reusable. Using a nation-wide average landfill disposal charge of $50/ton for non-hazardous waste (includhg transportation), disposal costs per square foot are calculated in Table 7-A as follows

SLAG:
7.6 lb/ft^2 (Consumption Rate) ÷
2000 lb/ton x $50/ton = <u>$0.19/ft^2</u>

STEEL
0.1 lb/ft^2 ÷ 2000 lb/ton x
$50/ton = <u>$0.003/ft^2</u>

If the slag waste is useable as a building material additive, disposal cost could be reduced to about $0.09/ft^2, still thirty times higher than the steel grit disposal cost.

Conditions for tank blasting on board will vary from the project test conditions. However, the comparative differences between slag and steel abrasive are valid and demonstrate the major savings possible in waste disposal costs when using steel abrasive.

7.4 Equipment and Operating Costs

This section offers a comparison of the costs associated with the purchase, operation and maintenance of equipment required for tank blasting with steel grit as compared to slag or other mineral abrasives. There are a number of manufacturers and suppliers around the country that can supply a wide range of equipment for use with either steel or mineral abrasives. Appendix B provides information for several suppliers.

Equipment used for abrasive blasting with disposable abrasives such as slags is less complex and thus somewhat less expensive to purchase initially. A basic system would include the following components:

- Air compressor (portable or stationary)
- Blast pot (to hold abrasive)
- Air dryers and after coolers
- Moisture and oil separators
- Blast nozzle and hoses
- Ventilation and dust collection equipment (for tank blasting)
- Vacuum equipment to collect spent abrasive

Costs for such a system would vary based on equipment type and manufacturer, and size of system required. Typical costs are summarized in Table 7-D. For comparison, a similar system with abrasive recycling is also included. Note that the same equipment is used for both systems, except that for recycling with steel grit there is the added cost of an abrasive recycling unit. Recycling with steel grit, therefore, adds about 15% to the initial equipment cost.

The individual components for a recyclable abrasive recovery system may be purchased separately, but the more common approach is to buy a complete unitized system, designed and engineered by an abrasive equipment manufacturer. These complete systems, which allow closed loop blasting and recovery, are available from several suppliers around the country. Section 8 describes a typical system. While recovery systems are used most effiaently with steel grit, they may be modified to process other reusable abrasives, such as aluminum oxide and garnet.

TABLE 7-D
EQUIPMENT, OPERATING AND MAINTENANCE COSTS
WITH AND WITHOUT RECYCLING

COMPONENT	APPROXIMATE PURCHASE COST	OPERATING COST* ($ PER HR)	MAINTENANCE COST* ($ PER HR)
Air Compressor (1300 cfm Portable)	$70,000	**$ 26.28** (Full Power)	$1.57
Blast Pot (Pressure Type)	$15.000	N/A	N/A
Air Dryers and After Coolers	'$ 2;000	$1.40	$0.05
Moisture and Oil Sep~~araers~~	$1,000	N/A	$0.20
Hoses (Hoses last approximately two months)	$600 (200 ft (@ $3/ft)	$1.80	N/A
Nozzles (two) (Nozzles last approximately two months)	$300 (2@ $150 each)	$0.90	N/A
Dust Collector (24,000 cfm)	$79,000	$6.00 (fuel) $1.00 (filters)	$0.10
Vacuum (PD Air Pump)	$51,000	$1.00 (fuel) $0.21 (filters)	$0.10
Abrasive Recycling Unit	$30,000	$0.14	$0.10
TOTAL - Without Recycling	$218,900	$38.59	$202
With Recvcling	$248,900	$38.73	$212

* Where applicable annual operating or maintenance cIw were divided by 2000 hours to come up with an houriy cost value. N/A Not **Applicable**

Typical operation and maintenance costs for equipment components are also shown in Table 7-D. Total operation and maintenance costs for a complete system without recycling would amount to about \$41 /hour or \$82,000/year based on continuous operation of 2,000 hours per year. These costs, when using recycled steel grit, would remain basically the same, since operating the recycling unit adds only pennies per hour.

7.5 Labor Costs

Labor is the largest cost element associated with an abrasive blasting job and subsequent clean up. This factor is, in turn, dependent on the prevailing wage rate of the particular area of the country. Labor costs to apply abrasives are also directly related to the production rate that can be achieved for the job. In other words, the faster an area can be blast cleaned, the lower the incurred labor cost. Production cleaning rate is a function of several variables, including operator skill, degree of cleanliness reqired, equipment type, surface condition, type of abrasive and nozzle pressure. As previously discussed, all other variables being equal, higher production rates can usually be achieved with steel abrasive.

Test results in Table 6-C show a cleaning **rate of 366 ft^2/hr for steel grit, which is twice the 176 ft^2/hr rate for slag.** Assuming an average labor rate of \$36/hr (including fringes), the labor cost factor for abrasive application is calculated as follows:

SLAG:
\$36/hr ÷ 176 ft^2/hr = <u>\$0.20/ft^2</u>

STEEL
\$36/hr ÷ 366 ft^2/hr = <u>\$0.10/ft^2</u>

The clean up times for spent abrasive (from Table 6-E) were 3.1 hours for copper slag and 2.2 hours for steel grit. Dust blow-down time must also be included in the total labor cost, since this is a necessary part of the clean up operation. Adding in the 30 minutes for slag and 17 minutes for steel grit, the total times become 3.6 hours for slag and 25 hours for steel grit. Therefore, the recovery cost factors are

SLAG:
\$36/hr x 3.6 hrs ÷ 1043 ft^2 = <u>\$0.124/ft^2</u>

STEEL
\$36/hr x 2.5 hrs ÷ 1043 ft^2 = <u>\$0.086/ft^2</u>

The total labor cost factor is calculated by combining the application and recovery factors

SLAG:
\$0.20/ft^2 + \$0.124/ft^2 = <u>\$0.324/ft^2</u>

STEEL
\$0.10/ft^2 + \$0.086/ft^2 = <u>\$0.186/ft^2</u>

Thus, the total labor cost for blast cleaning the test area would be

SLAG:
1043 ft^2 x \$0.324/ft^2 = <u>\$ 337.93</u>

STEEL
1043 ft^2 x \$0.186/ft^2 = <u>\$ 194.00</u>

This comparison indicates that the total labor costs using a slag abrasive are 1.7 times the costs using steel abrasive.

8. RECOMMENDED PROCEDURES FOR TANK BLASTING WITH RECOVERABLE STEEL ABRASIVE

8.1 Current Commercial Specifications

Tank blasting currently involves the use of non-recyclable mineral abrasives, which are purchased according to the Steel Structures Painting council (SSPC) specification SSPC-AB-1, Mineral and Slag Abrasives, June 1, 1991. In addition, most mineral abrasive suppliers provide a specification sheet with their abrasive product giving sizing limitations, chemistry, heavy metal and free silica values. Since mineral abrasives are generally not recycled there are no limits on durability or recyclability.

Steel abrasives, on the other hand, are much more closely specified. Steel abrasives are purchased to a strict sizing specification as defined by the proposed new SSPC specification for steel abrasives (see Appendix C) and must also meet the durability standard that is included in this same specification.

8.2 Current U.S. Navy Specification

The Navy has a specification for non-metallic abrasives, MIL-A-22262A (SH), which is currently being revised. This specification is primarily concerned with setting limits on heavy metals and free silica, both of which could create a hazardous environment when blasting. Friability of abrasive is also addressed but only to the extent that the abrasive meets the California Air Resources Board (CARB) limits for dry abrasive blasting.

The Navy specification does not address performance of mineral abrasive. The shipyards therefore, should have ways of evaluating whether or not a given mineral grit will perform and thus meet the job requirements. There is a need for a good performance specification for non-metallic abrasives.

For steel abrasives, the Navy references several specifications, most of which are related to performance. The primary Navy specifications are General Services Administration (GSA) Commercial Item Description (CID) AA-1041B Steel Grit and AA-1042B Steel Shot. These specifications define abrasive sizing, durability and chemistry. In addition to these specifications, the Navy should be incorporating the new SSPC performance specification as well as the SSPC Recyclable Abrasive Cleanliness Specification.

8.3 Recommended Procedures for Blast Cleaning and Recovery

The test results reported in this study have demonstrated that a recyclable steel abrasive offers the greatest opportunity for significant productivity improvements in tank blasting. Steel abrasives also minimize environmental impact because they are recyclable, minimize dust and contain no hazardous elements. The discussion that follows outlines a typical production scenario using a steel grit recycling system. Recent discussions with shipyard personnel as well as others in related industries have contributed to the development of this scenario.

In addition to the systems descriptions below, Appendix D provides a sample Process Control Procedure (PCP) format that was developed for tank blasting with steel abrasive aboard U.S. Navy ships. This sample PCP is intended to be used as a guide to assist any shipyard in developing their own process procedures.

Although the format was developed to meet Navy requirements, it can be easily adapted to serve as a process control document for commercial tank blasting as well.

For tank blasting, abrasive blasting and recovery cannot generally occur simultaneously if the tanks are small and confined. Therefore, a holding tank or tanks should be set up to hold sufficient steel abrasive to support a full compliment of blasters for a single shift. Air dryers, dehumidification and dust collectors should also be integrated into the system to eliminate moisture in the blast pots, rust-back of the blast cleaned surface and excessive dust during blasting. A typical set-up is shown schematically in Figure 8.1. To take full advantage of steel abrasive's productivity, high pressure compressors capable of up to 150 psi nozzle pressures should also be utilized. After blast cleaning, abrasive recovery is best accomplished using a vacuum pickup system and collection tank as shown in Figure 8.2. If the tanks being blasted are of sufficient size however, it may be advantageous to incorporate some mechanical recovery system while blast cleaning, such as conveyors and augers. (See Appendix B for recommended suppliers.)

Following is a generalized outline of the type of equipment needed for an effective steel grit blast cleaning recovery and recycling system. All components described are currently available "off-the-shelf" items. Included in this outline are the key performance requirements to meet the needs of the job. A list of the suppliers of each component is given in Appendix B.

Blast Cleaning

Initial blast cleaning can be accomplished by any of the currently available shipyard blast pots. Large capacity, 10 - 20 ton pressurized pots are preferable since they will allow continuous blasting by two or more blasters for an entire eight hour shift without having to refill the blast pot. Blast cleaning equipment capable of operating at 150 psi is recommended to take advantage of the increased blast cleaning efficiencies when blast cleaning with 120 - 150 psi nozzle pressures. To maintain productivity, regular additions of new abrasive should be added to the working mix. A good "rule of thumb" is: after every 10- 20 cycles add 1 - 2% of new abrasive.

Air Compressors

As noted above, compressors capable of operating to produce 120-150 psi nozzle pressures are preferable. However, conventional yard air or compressors can also be used as long as the compressed air source generates nozzle pressures of 90-100 psi.

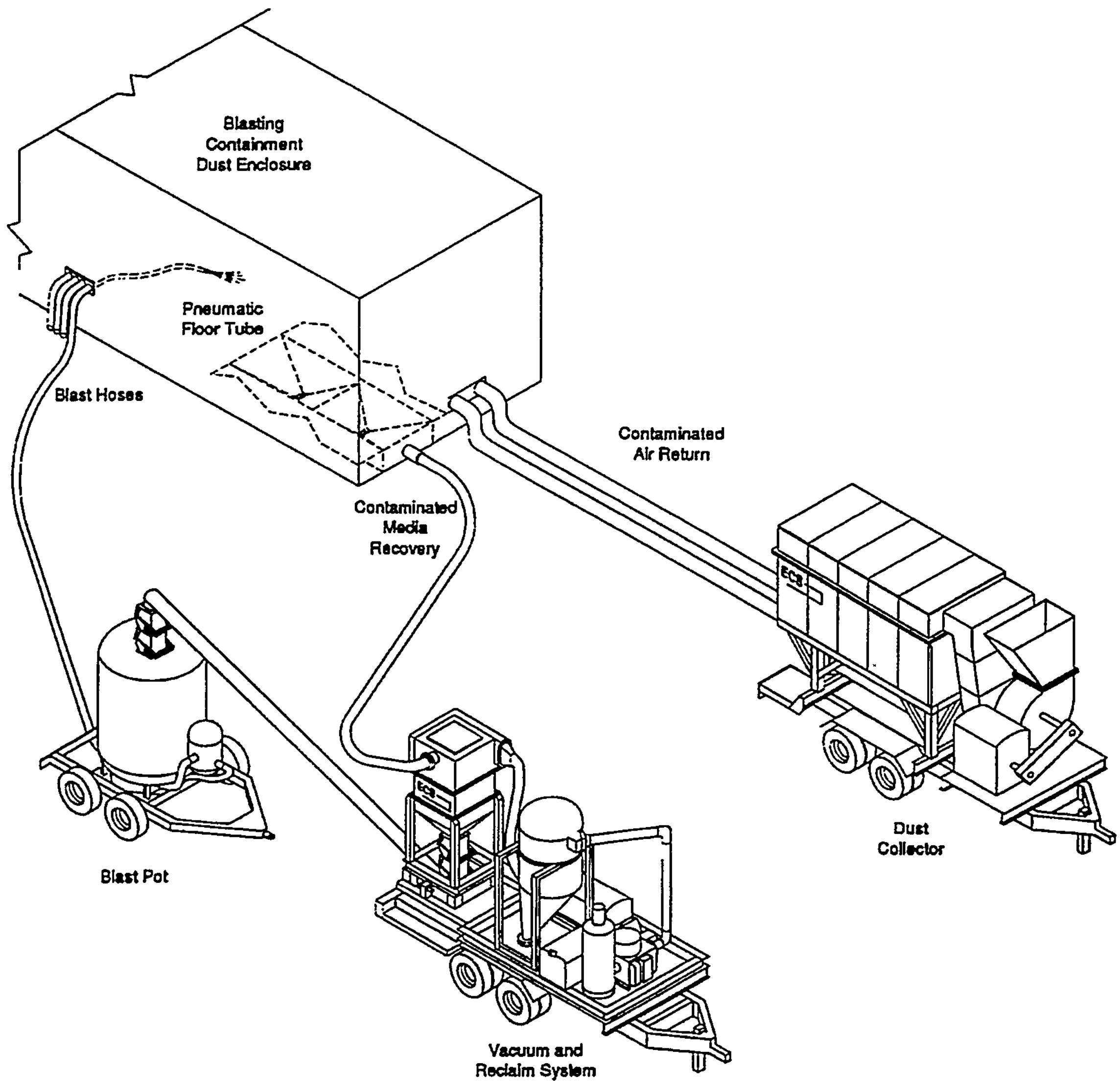
Dust Collectors

Although steel abrasive itself generates little dust, dust is generated during tank blasting by paint, rust and scale being removed from the steel surface. To maximize worker safety and productivity and improve visibility, large capacity (10,000 -20,000 cfm) dust collectors should be used for dust removal during blasting. Maintaining air flows in the tank of 50-100 ft/min are generally recognized as optimum for dust control.

Dehumidification

The high humidity environments of most shipyards causes condensation on the blast cleaned steel surface, which can lead to flash rusting. Dehumidification is recommended to assure a rust free and dry blast cleaned surface for subsequent painting. The most common dehumidification system for shipyard use is the dry honeycomb desiccant wheel system. A

Figure 8.1 System Schematic



Schematic layout of a steel abrasive blast and recovery system with dust collector.

9,000-10,000 cfm unit is large enough and portable for most shipyard applications. For energy conservation, the clean air discharge from the dust collector can be sent through the dehumidifier and back into the tank This essentially recirculates the dry air.

Abrasive Recovery

After blast cleaning, abrasive recovery is usually accomplished using some type of vacuum system connected to a suitable dust collector. There are currently three types of vacuum systems:

- Liquid ring vacuums
- Positive displacement (PD) vacuum pumps
- Compressed air eductor vacuums

For efficient vacuuming, the recovery system should include the following:

- Hoses 3 - 6“ I.D. vacuum hoses fitted with 1/2” screens over the ends. The screens will prevent sucking up trash, large pieces of rust scale and paint chips that could plug the abrasive recovery system.

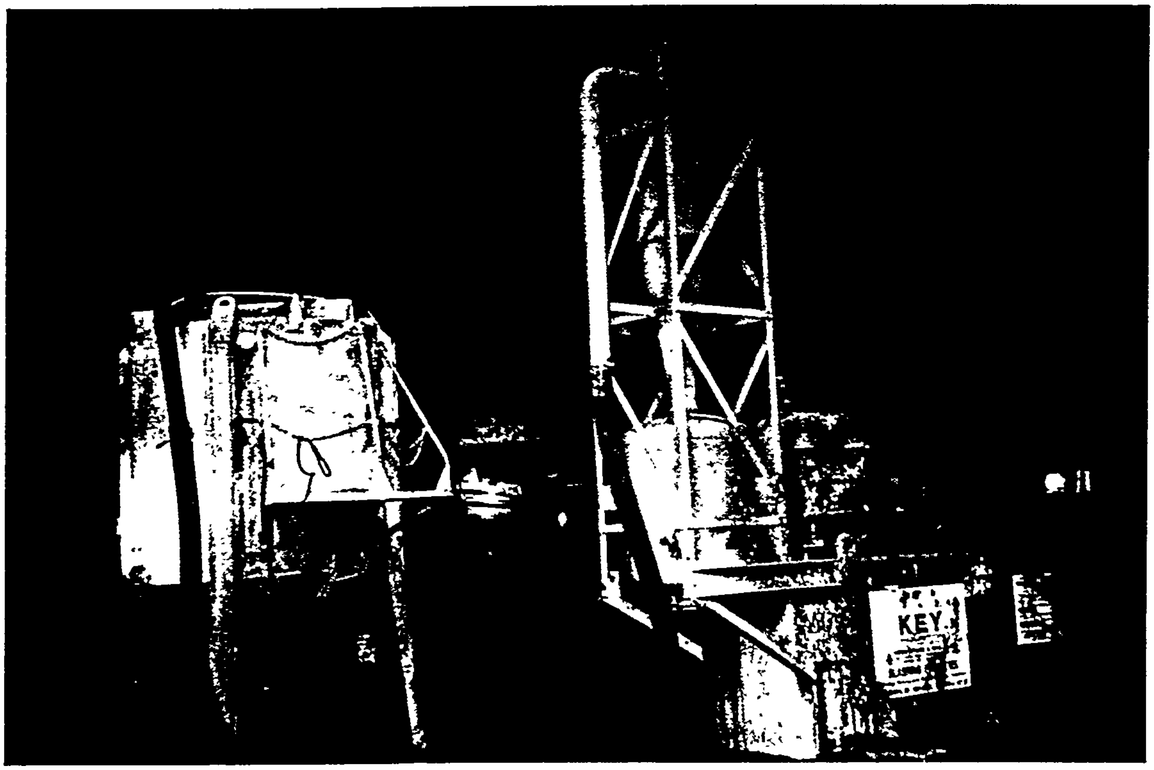
- Collection Tank This tank acts as a drop-out chamber for the vacuumed abrasive and as a holding tank, and allows metering of the recovered abrasive to the abrasive cleaning station. This collection tank could be any existing large abrasive tank

- Abrasive Cleaning Station: The cleaning station design is the most critical portion of the abrasive recovery system and must contain two major components a magnetic drum separator to remove paint chips and non-magnetics, and an airwash system to remove dust and fines. These two components should be integrated to process five to ten tons of reclaimed abrasive per hour.

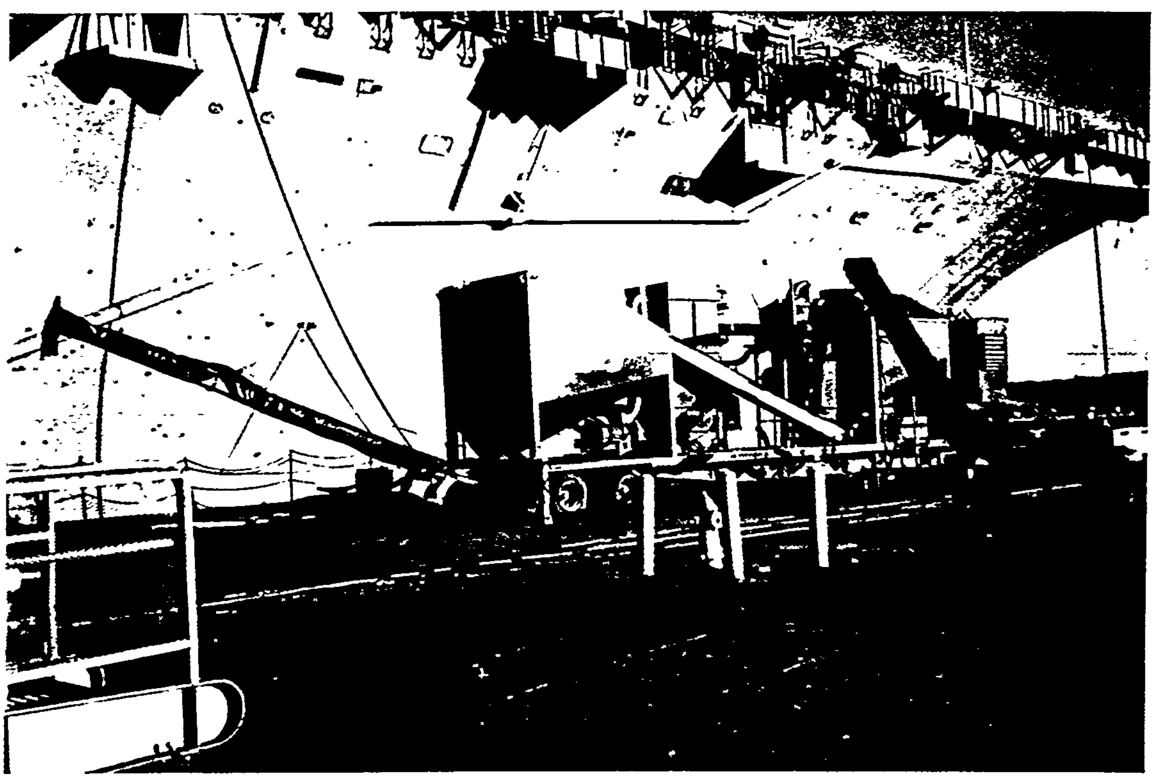
  Dust Collector: A small 500-1000 cfm dust collector to collect dust and fines removed by the airwash.

- Cleaned Abrasive Storage Tank After the abrasive has been run through the abrasive cleaning station, the cleaned abrasive is returned to an abrasive storage tank or hoppers for reuse.

All the equipment noted above is currently available and being used in abrasive recovery and recycling systems. Appendix B lists most of the manufacturers currently in the abrasive recovery and recycling business. A system setup at Philadelphia Navy Shipyard, using the components described above, is shown in Figure 8.3. Note that the system is skid mounted to facilitate movement to and from the job site.



Figu .2 Water- cu m Un



Figu .3 R co ery lea ıpya

9. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Mineral abrasives, used once and discarded, historically have been the abrasive of choice for a major portion of shipyard blast cleaning. Shipyards today are faced with a changing workplace that requires more efficient use of materials, waste minimization, and the use of high-tech coatings to mention a few. These changes are causing the industry to rethink current methodologies and look for ways to meet the strict environmental requirements and the need for higher productivity to remain competitive. Based on the results of this project, recyclable steel abrasive appears to fit the needs of this new workplace.

This project explored and compared the various aspects of tank blasting with disposable mineral abrasives and recyclable steel grit. Project research included a survey of abrasive blasting methods at various shipyards around the country, as well as a look at current blasting practices in the bridge maintenance industry. An overview of environmental, health and safety issues, including waste disposal, was also presented.

Production testing was conducted to compare abrasive application and recovery using copper slag and steel grit in a simulated tank environment. An economic analysis based on the test results was performed to compare the various cost factors for a typical tank blasting job. The study also describes recommended equipment and procedures for tank blasting with recyclable steel abrasive.

The primary conclusion resulting from this study is that tank blasting with steel grit is an economically and environmentally viable replacement for the current practice of blasting with disposal mineral abrasives. Several environmental and health issues can be favorably addressed with the use of recyclable steel grit, such as improved air quality through reduced dust generation and the significant minimization of solid and hazardous waste. Based on the project test results, the economic advantages of using steel grit also appear to be substantial. Although the testing was performed in a simulated tank rather than on board a ship, valid performance comparisons were possible. Significant findings can be summarized as follows:

- Overall job costs using steel grit, including material, labor and waste disposal, are about one-half the costs for copper slag.

- Blasting and clean up labor costs for steel grit are about 60% of the costs for slag.

- The biggest savings with recyclable steel abrasive are in the material cost (one tenth the cost of slag) and waste disposal cost (less than 2% of the slag cost).

- The largest single cost factor for copper slag is material cost, which is about one third of the total job cost.

- The largest single cost factor for steel grit is the cost to operate and maintain the recycling equipment, which is almost one half of the total job cost.

This study has also led to conclusions and recommendations with respect to current specifications and procedures for tank blasting with recoverable steel grit. The U.S. Navy does not currently have an approved Process Control Procedure (PCP) for the use of steel grit in tanks. This was the primary reason that production testing for this project could not be conducted aboard a Navy ship, as originally intended. At the time of this writing, a performance specification and a PCP were being developed by NAVSEA and are expected to be issued sometime in 1993. The authors of this report would highly recommend the incorporation of the newly-drafted Steel Structures Paint Council *(SSPC)* performance and cleanliness standard for steel abrasive into the Navy specification.

In addition to establishing the feasibility of tank blasting with steel grit, this project has identified several key parameters and variables for future study. Preliminary testing at elevated nozzle pressure and finer steel grit particle size indicate that these two parameters may have the potential to significantly increase productivity. Additional testing would be required to quantify the optimum nozzle pressure and particle size combination to maximize productivity without sacrificing recyclability.

One of the main issues to be addressed with respect to using a recyclable abrasive is ensuring the cleanliness of the abrasive during the recycling process. For a recycling system to be truly effective, the abrasive being recycled must have a cleanliness close to that of new abrasive. The abrasive must be basically free of contaminants such as moisture, oil, salt and paint residue. To demonstrate cleanliness, the abrasive should be run through several blast and recovery cycles — at least ten — with a follow-up cleanliness test after each cycle. The new SSPC abrasive cleanliness standard for recycled steel abrasive can be used for this analysis. Since the test scope of this project did not allow for multiple recycles, future testing should incorporate a larger test area to permit numerous recycles.

A Phase II follow-on project has been proposed as part of the 1994 NSRP program to address the above recommendations.

10. REFERENCES

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4. Society of Naval Architects and Marine Engineers, Panel O-23, TANK COATING GUIDE FOR BALLAST TANKS OF ALL VESSELS AND CARGO TANK OF PETROLEUM TANKERS, Technical and Research Bulletin 4-23, March 1991.

5. Steel Structures Painting Council, GOOD PAINTING PRACTICE, 2nd ed., 1989.

6. Steel Structures Painting Council, SYSTEMS AND SPECIFICATIONS, 6th ed., 1991.

7. K. A. Trimber, KTA-Tator, Inc., INDUSTRIAL LEAD PAINT REMOVAL HANDBOOK, 1991.

8. U.S. Department of Transportation, Maritime Administration, PROCEDURE HANDBOOK FOR SURFACE PREPARATION AND PAINTING OF TANKS AND CLOSED AREAS, September 1981.

9. U.S. Department of Transportation, Maritime Administration, PROTOTYPE MINERAL ABRASIVE RECLAIMER SHIPYARD OPERATION, March 1987.

10. U.S. Navy and National Steel and Shipbuilding Co., DETERMINATION OF PARTICULATE AND DUST CONCENTRATION DURING SHIPYARD DRYDOCK SANDBLASTING OPERATIONS, NSRP #0365, September 1992.

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APPENDICES

APPENDIX A

SAMPLE SHIPYARD SURVEY FORM

SHIPYARD QUESTIONNAIRE

Blast Cleaning Operations

shipyard ______________________ Person Interviewed ______________________________

Phone No. ______________________________________

Plates and Shapes:

- Abrasive used (steel, mineral slag, other)
- Type (shot, grit)
- Method of blast cleaning (centrifugal wheel, nozzle)
- Profile (mils)
- Degree of cleanliness: (SP6, 10,5)
- If abrasive recycled
  - method of recovery
  - method of abrasive reclamation
- Coating systems: (thickness and type)

Subassemblies

- Abrasive used (steel, mineral slag, other)
- Type (shot, grit)
- Method of blast cleaning (centrifugal wheel, nozzle)
- Profile (mils)
- Degree of cleanliness (SP6, 10,5)
- If abrasive recycled
  - method of recovery
  - method of abrasive reclamation
- Coating system(s): (thickness, type)

Aboard-Ship Blast CIeaning

- Abrasive usecd: (steel, mineral slag, other)
- Type: (shot or grit)
- Method of blast cleaning: (nozzle, vacublast, other)
- Profile (mils)
- Containment
- Ventilation: (cfm)
- Abrasive recovery method
- Abrasive reclamation method
- Coating systems (thickness and type)

APPENDIX B

EQUIPMENT MANUFACTURERS DATA

EQUIPMENT MANUFACTURERS DATA

Following is a list of manufacturers of the equipment noted in Section 8.3, Recommended Procedures for Blasting and Recovery. This is only a partial list of manufacturers and is presented as a guide. The manufacturer's address, phone number and contact person are also given.

Dehumidification

- Enviro-Air Control Corporation
- J.G. Systems, Inc.
- Munters Moisture Control Service

Dust Collectors

- Environmental Containment Systems
- IPEC Advanced Systems, Inc.
- J.G. Systems, Inc.

Vacuum Recovery Equipment

- BMSI, Inc.
- IPEC Advanced Systems, Inc.
- Vacuum Engineering Corporation
- Vacmasters of Denver

Air Dryers

- Van Air Systems, Inc.
- Deltech Engineering, L.P.

Blast and Recycling Systems

- Advanced Recycling Systems, Inc.
- IPEC Advanced Systems, Inc.
- Clemco Industries Corporation
- Environmental Containment Systems
- Surface Preparation Machinery, Inc.

Abrasive Collection/Storage Bins

- J.G. Systems

Conveyors and Augers

- TETKO, Inc.
- FMC Corporation

INDEX TO MANUFACTURERS

Advanced Recycling Systems, Inc.
1089 N. Hubbard Road
Lowellville, OH 44436-9737
216-534-3330

American Welding Inc.
P.O. Box 119
Maumee, OH 43537
Ted Weaver
800-537-3370

BMSI, Inc.
P.O. Box 410
Seahurst, WA 98062
Neil MacKinnon
206-433-6947

Clemco Industries Corporation
One Cable Car Drive
Washington, MO 63090
Patti Roman
314-239-0300

Deltech Engineering, L.P.
P.O. Box 667
New Castle, DE 19720
Bob Simons
302-328-1345

Enviro-Air Control Corporation
1523 North Post Oak Road
Houston, TX 77055
Charles H. Wyatt
713-681-3449

Environmental Containment Systems
P.O. Box 58763
Houston, TX 77258
Marshall Seavey
713-4743734

FMC Corporation
Material Handling Equipment Div.
Homer City, PA 15748
412-479-8011

IPEC Advanced Systems, Inc.
9 Spinnaker Street
North Kingstown, RI
Gerald McNamara
800-822-IPEC

J.G. Systems, Inc.
P.O. Box 840247
Houston, TX 77284
Bob Jellerson
713-466-4233

Munters Moisture Control Services
79 Monroe Street
Amesbury, MA 01913
W. Craig Fillman
508-388-4900

Surface Preparation Machinery, Inc.
708 North First Street, Suite 331
Minneapolis, MN 55401
Brian Williams
800-800-7761

TETKO, Inc.
333 South Highland Ave.
Briarcliff Manor, NY 10510
914941-7767

Vacmasters of Denver, Inc.
6114 West 55th Avenue
Arvada, CO 80002-2704
Richard Roatch
303-467-3801

Vacuum Engineering Corporation
3374 West Hopkins Street
Milwaukee, WI 53216
Scotty Johnstone
4144444010

Van Air Systems, Inc.
2950 Mechanic Street
Lake City, PA 16423
Sharon Mleczko
814-7742631

APPENDIX C

DRAFT OF PROPOSED SSPC SPECIFICATION FOR STEEL ABRASIVES

(NOTE The new SSPC specification is targeted for release prior to year end, 1993. Copies will be available from the Steel Structures Painting Council.)

STEEL STRUCTURES PAINTING COUNCIL
ABRASIVE SPECIFICATION SSPC-XAB2X
Cast Steel Abrasive

1. Scope

1.1. This specification covers the requirements for granular, cast steel abrasive for use in cleaning either coated or uncoated steel surfaces for the removal of rust, mill scale, paint or other surface coating systems and for general blast cleaning applications utilizing steel abrasive.

1.2. The abrasives covered by this specification are primarily intended for use in recycling systems.

2. Description

2.1. This specification covers two types of cast steel abrasive steel shot and steel grit.

2.2. Each type of cast steel abrasive has the following size classification:

Type Cast Steel Abrasive	Size Classification
Steel Shot	S460, S390, S330, S280, S230, S170, S110, S70
Steel Grit	G14, G16, G18, G25, G40, G50, G80

2.2.1. The requirements for each size classification are given in Section 4.3.1.

3. Reference Standards

3.1. SSPC Standards

SSPC-SP 5 White Metal Blast Cleaning

3.2. ASTM Standards

A 370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products

C 128 Test Method for Specific Gravity

C 136	Test Method for Sieve Analysis of Fine Sand and Coarse Aggregates
E 29	Standard Practice for Using Digits in Test Data to Determine Conformance with Specifications
E 350	Standard Test Method for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron

Application for copies of ASTM Standards should be addressed to ASTM, 1916 Race Street, Philadelphia, PA 19103.

4. Requirements

4.1. General Physical and Chemical Properties.

The abrasive shall meet all the requirements of Sections 4.2 through 4.5 (See Note 7.1.).

4.2. Manufacturing Cast Steel Abrasive.

Cast steel abrasive shall be newly manufactured or remanufactured as defined below.

4.2.1. Newly Manufactured. These are abrasives manufactured for virgin raw materials (recirculated or used show or grit is not permitted).

4.2.2. Re-Manufactured. In accordance with Section 4.2, the term "remanufactured" means materials which have been collected or recovered from solid waste and reprocessed to become a source of raw materials as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or recirculated products are allowed under Section 4.2 where "newly manufactured" or "remanufactured" is specified.

4.3. Physical Properties

4.3.1. Size Classification. The abrasive size classification shall meet the size requirements for cast steel shot in Table 1 and cast steel grit in Table 2.

4.3.2. Appearance. Using a 10X microscope or magnifying glass, the steel shot shall be predominantly rounded particles. Steel grit shall be a mixture of irregular shaped and angular steel particles in accordance with paragraphs 5.2 and 5.3.8.

4.3.3. Specific Gravity. When tested in accordance with Section 5.3.3, the specific gravity of the steel abrasive shall be not less than 7.0 g/cc.

4.3.4. Hardness. The average steel abrasive hardness shall be between C 35 and C 50 on the Rockwell scale.

4.3.5. Durability Performance. When tested in accordance with 5.3.6, the steel abrasive shall conform with the durability requirements shown in Table 3, Steel Grit and Table 4, Steel Shot.

4.4. Chemical Properties

4.4.1. When tested in accordance with 5.3.6, the steel abrasive shall conform with the following limitations.

Iron	97.00%, minimum
Carbon	1.50%, maximum
Manganese	1.20%, maximum
Phosphorus	0.05%, maximum
sulfur	0.05%, maximum
Silicon	1.50%, maximum

4.5. Cleanliness

When tested in accordance with Section 5.3.8, the steel abrasive shall be free of dust, oil, grease, corrosion, and other contaminants. Corroded or rusted steel abrasive shall be considered unacceptable.

4.6. Cleaning Performance

When tested in accordance with 5.3.7, the abrasive shall conform to the performance requirements as shown in Table 5 for shot and grit. If agreed upon by purchaser and supplier, an alternative cleaning performance criterion may be used. (See Note 7.3).

5. Quality Assurance Provisions

5.1. Lot Formation

For purposes of inspections and testing a lot shall consist of all shot or grit produced utilizing the same feed lot of raw materials. (See Note 7.2).

5.2. Visual Examination

The sample steel abrasive media shall be examined for rust. The presence of rust in excess of a slight red rust coloring of the abrasive particle shall be cause for rejection.

5.2.1. Frequency of Examination. The examination described in Section 5.2 shall be performed on a lot-by-lot basis.

5.3. Procedures

5.3.1. Frequency of Testing. Unless otherwise specified in the contract or purchase order, testing for size, durability and cleanliness shall be performed on each lot of abrasive. Testing for density, chemical composition, hardness and extraneous material shall be performed initially to establish conformance and thereafter anytime that the source of raw material changes. In the event multiple sources of raw material are used, material from each source shall be tested.

5.3.2. Size. The abrasive sizing shall be tested in accordance with ASTM C 136.

5.3.3. Specific Gravity. Specific gravity shall be determined in accordance with ASTM C 128.

5.3.4. Chemical Composition. Chemical composition shall be determined in accordance with ASTM E 350.

5.3.5. Hardness. Hardness values shall be obtained in accordance with ASTM A 370 utilizing a microhardness tester with a 500 gm load. Measurements taken in Knoop hardness numbers shall be converted to Rockwell C Scale. (See Note 7.4).

5.3.6. Durability Test. The following mechanical shot and grit durability test uses the complete breakdown or 100% replacement test method. (See Note 7.5).

5.3.6.1 Procedure

1. Using a calibrated* standard durability test machine (see Part 2-Calibration Procedure), weigh out 100 grams (± 0.1 g) of new abrasive.

2. Place 100 g sample in test machine and run for 500 passes.

3. Remove sample from test machine and screen sample on appropriate take-out screen (see Table 1).

4. Hand screen sample on take-out for approximately 3 minutes.

5. Weigh material remaining on take-out screen and record weight.

6. Add sufficient new abrasive to abrasive remaining on take-out screen to again makeup 100 g sample and place sample back in test machine for an additional 500 passes.

7. At the conclusion of 500 passes, repeat steps 3 through 6. Continue repeating steps 3 through 6 until the cumulative loss is 100 g or more.

8. Interpolation of the end point or total passes required to equal 100% Life Test is as follows:

$$\frac{\text{500 Pass Per Run}}{\text{Wt. Loss last Run}} \times \begin{matrix}\text{100 - Cumulative} \\ \text{before 100\% Loss}\end{matrix} \quad \begin{matrix}\text{Cumulative Passes} \\ \text{before 100\% loss}\end{matrix}$$

9. Record end point value and compare with standard values show on Table 1. Durability of test abrasive should meet or exceed value shown in Table 1 for the same size and type of abrasive.

* Use manufacturer's test for calibration. Calibration should be performed once every 20 durability tests.

5.3.6.2 Apparatus. Durability tests shall be performed using an Ervin Industries Inc.* or equivalent shot/grit test machine, properly calibrated in accordance with the manufacturer's instructions.

5.3.7. Performance Test Procedure. Using a standard Ervin Durability Test Machine or equivalent (as defined in Section 5.3.6.2), remove the bell housing plus and replace the plug with the alrnen strip holder. Before inserting the strip holder, mount on the strip holder a standard test strip of 2½ x ¾ x 3/16" hot rolled flat bar with intact mill scale, ASTM Grade A 283. The holder with test strip is inserted into the Ervin Test Machine Bell Housing along with 20 g of new abrasive media to be tested. The test is then run for the specified revolutions (cycles) of the beater housing as shown in Table 5 for specific abrasive size being tested. After each test the test bar is removed and evaluated for degree of cleanliness base on SSPC SP 5, White Metal Blast Cleaning. The abrasive media used for the test is also removed. If the surface is not cleaned to white metal, the abrasive fails to meet the cleaning performance standard.

5.3.8. Abrasive Cleanliness. First separate all magnetic particles from a 100 gram sample using a magnet and calculate and record the percentage by weight of non-magnetic matter remaining. Discard the non-magnetic matter. Next, partially fill a clean glass or plastic jar or beaker with potable water. Place the magnetic particles obtained in the jar or beaker using a clean spoon. Cover the containers and shake contents vigorously. Observe the surface of the water and container:

Accept sample if Less than or equal to 0.2% by weight of non-magnetic matter and clouding or discoloration of the water, but no oil film or slick on the surface of the water.

Reject sample(s) W More than 0.2% by weight of non-magnetic matter and / or oil film or slick on the surface of the water and sides of the container.

6. Disclaimer

6.1. While every precaution is taken to insure that all information furnished in SSPC specifications is as accurate, complete, and useful as possible, SSPC cannot assume responsibility nor incur any obligation resulting from the use of any materials, paints or methods specified therein, or of the specification itself.

7. Notes

7.1. Disposal of abrasives should be in compliance with all applicable Federal, State, and local regulations. It should be noted that the spent abrasive may contain hazardous paint and other foreign matter.

7.2. The importance of properly obtaining a sample cannot be over emphasized. All subsequent analyses performed on the selected sample are likely to be affected by particle size, so it is imperative that every reasonable effort be made to select the sample in a way that will assure proper representation. Therefore, it is important to select the proper sampling location and to use proper techniques to select the sample. The following guidelines should be kept in mind when deciding on a sampling method:

7.2.1. If possible, the sample material to be tested should be sampled when it is in motion, such as at a conveyor transfer point or a discharge chute.

7.2.2. Several small samples of the entire product stream should be taken rather than one large sample.

7.3. Very limited data is currently available regarding this procedure. The SSPC Abrasive Committee is seeking data from other laboratories and planned SSPC laboratory testing.

7.4. Metallic abrasives sometimes contain internal shrinkage or voids which remain undetected beneath the surface in a mounted and polished sample. These hidden cavities cause a non-uniform hardness indentation and false hardness reading. These indentations must be ignored when testing for hardness.

TABLE 1
STEEL SHOT SIZE SPECIFICATIONS

SCREEN NO.	SCREEN SIZE	SHOT SIZE 460	390	330	280	230	170	110	70
10	0.0787	all pass							
12	0,0661	5% max	all pass						
14	0,0555		5% max	all pass					
16	0,0469	85% min		5% max	all pass				
18	0.0394	96% min	85% min		5% max	all pass			
20	0.0331		96% min	85% min		10% max	all pass		
25	0.0280			96% min	85% min		10% max		
30	0.0232				96% min	85% min		all pass	
35	0,0197					97% min	850% min	10% max	
40	0,0165						97% min		all pass
45	0,0138							80% min	10% max
50	0.0117							90% min	
80	0.0070								80% min
120	0.0049								90% min

Screen opening sizes and screen numbers with maximum and minimum cumulative percentages allowed on corresponding screens.

TABLE 2
STEEL GRIT SIZE SPECIFICATIONS

SCREEN NO.	SCREEN SIZE	GRIT SIZE						
		G14	G16	G18	G25	G40	G50	G80
10	0.0787	all pass						
12	0.0661		all pass					
14	0.0555	80%		all pass				
16	0.0469	90%	75%		all pass			
18	0.0394		85%	75%		all pass		
25	0.0280			85%	70%		all pass	
40	0.0165				80%	70%		all pass
50	0.0117					80%	65%	
80	0.0070						75%	65%
120	0.0049							75%

Screen opening sizes and screen numbers with maximum and minimum cumulative percentages allowed on corresponding screens.

TABLE 3
STEEL GRIT

STEEL ABRASIVE SIZE	MINIMUM DURABILITY CYCLES TO COMPLETE BREAKDOWN	TAKE-OUT SCREEN **SIZE**
G14	**2000**	**40** mesh
G16	2100	40 mesh
G18	2200	40 mesh
G25	2300	50 mesh
G40	2300	50 mesh
G50’	2000	70 mesh
G80*		

* Abrasive sizes G50 and G80 cannot be accurately tested due to limitations of the test apparatus in retaining these sizes.

TABLE 4
STEEL SHOT

STEEL SHOT **SIZE**	MINIMUM DURABILITY CYCLES TO COMPLETE **BREAKDOWN**	TAKE-OUT SCREEN SIZE
S460	**2200**	**40** mesh
S390	2300	40 mesh
S330	2400	50 mesh
S280	2550	50 mesh
S230	2550	50 mesh
S170	2550	50 mesh
S110*	2000	70 mesh
S70’	•	•

Abrasive sizes S110 and S70 cannot be accurately tested due to limitations of the test apparatus in retaining these sizes.

TABLE 5
CLEANING PERFORMANCE STANDARDS
CYCLES REQUIRED TO ACHIEVE **WHITE METAL (SP 5) SURFACE**
FOR VARIOUS SIZED STEEL SHOT AND GRIT MEDIA

ABRASIVE SIZE		WEIGHT ABRASIVE	NUMBER OF CYCLES	DEGREE OF CLEANLINESS
GRIT	SHOT			
G14	S460	20 gm	90	SP-5
G25	S330	20 gm	70	SP-5
G40	S280	20 gm	***60***	***SP-5***
G50	***S230***	***20*** gm	40	SP-5
G60	Silo	20 gm	60	SP-5

APPENDIX D

SAMPLE FORMAT FOR PROCESS CONTROL PROCEDURE (PCP) FOR TANK BLASTING WITH STEEL ABRASIVE ABOARD NAVAL VESSELS

SAMPLE FORMAT FOR PROCESS CONTROL PROCEDURE (PCP)
FOR TANK BLASTING WITH STEEL ABRASIVE ABOARD NAVAL VESSELS

1.0 SCOPE

This document specifies the procedures by which [Insert Name *of Shipyard] will* comply with the requirements for abrasive blasting of shipboard tanks interior metal surfaces utilizing cast steel grit materials.

1.1 TITLE: CAST STEEL GRIT ABRASIVE BLASTING

2.0 REFERENCES

2.1 NAVSEA Standard Item 009-09; Process Control Procedure.

2.2 NAVSEA Standard Item 009-32; Cleaning and Painting Requirements.

2.3 Commercial Item Description (CID) No.s 1041B and 1042B, regarding Steel Grit and Steel Shot performance utilization for general blasting purposes, respectively.

2.4 ***ASTM D-4940-89;*** Standard Test for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives.

2.5 Mil Spec - MIL-A-22262A, dtd 14 Feb 1989, “Abrasive Blasting Media Ship Hull Blast CIeaning”

3.0 REQUIREMENTS

3.1 Submit a Process Control Procedure to the cognizant Supervisor for review.

3.1.1 ***Ensert Name and Address of Shipyard]***

____

(Contractor’s Name and Address)

3.1.2 Use of Cast Steel Grit Materials for Abrasive Blasting of Shipboard Tanks Interior Metal Surfaces

(Process Title)

Ensert Shipyard’s PCP Number]

Process Control Procedure No. __________________________

____

(Process Number)

Revisions:

____

(Date Developed)

3.1.3 PROCESS DESCRIPTION

In preparing the interior surfaces of tanks to undergo painting, the Contractor will use a lot mix of steel grit abrasive blasting materials commensurate with the job at hand, in accordance with reference (2.2).

A. The cast steel grit / shot mix, Type 1,2, or 3, with Rockwell / C of C-40 to C-SO hardness, in accordance with ref. (23), will be used as the abrasive blasting material to clean the tank interior metal surfaces being prepared for painting / preservation per reference (21).

B. The Contractor wilI institute a rigorous testing program in which it will observe and test the quality of the steel shot / grit characteristics and cleanliness for further reclassification on an ongoing basis throughout the tank cleaning process. This will ensure optimum grit quality and cleanliness. The grit after inspection will be returned, along with any necessary replenishment of “Make-up Grit to the grit blasting source. This degree of testing and control will ensure the quality of grit being utilized.

c. Blast Equipment & Recovery Systems

Ensert ***name and description of abrasive blast machines to be used by the shipyard.]***

[Insert name and description of vacuum recovery and reclassifier system to be used.]

Applicable data sheets and instructions for blast equipment and recovery systems are included as an enclosure to this Process Control Procedure.

D. Method & Type of Equipment to be Used for Testing Cleanliness of Recycled Grit

Prior to commencement of blasting operations, the Contractor will, through a series of tank cleanliness preinspections, ensure that salt / chemical contamination is controlled.

The Contractor fully recognizes that abrasive materials must be clean, otherwise contamination on the abrasive will be transferred to the surface being blasted. The most dangerous contaminates on abrasives are water, oil, grease, and chloride (or sulfate containing salt). Any of these contaminants, once transferred to steel being worked, could cause premature failure of the coatings applied over them. At least one inspection method will be used to detect oil and grease. An abrasive material sample will be placed in a clean glass jar containing clean water. The contents will be vigorously shaken and observed. If a film of oil appears on the surface of the water, then the abrasive is not clean enough for continued blasting utilization. The steel grit lot will then be reclassified and retested further to ensure it passes the test for oil content as contained in reference (2.5). A periodic sampling/visual inspection of this will be conducted at the beginning of an abrasive cleaning effort, throughout the blasting operation, and before adding reclassified grit back to the blast supply source. Concurrent with this process, a visual inspection will be accomplished to determine if the source abrasive material used in the blasting process is dry, and for the presence of any other possible contaminants.

A conductimetric analysis for salt contamination may be conducted on-site with a minimum of field equipment and process disruption. The Contractor intends to require the use of the test method outlined in ASTM-D-4940, wherein a slurry of equal amounts by volume (300 roil) of pure water and abrasive is agitated, the agitated solution is filtered, and then checked for conductivity with a commercial conductivity bridge and conductivity cell as specified in ASTM-D-4940. According to ASTM-D-4940, a reading of 500 µmho/cm (microsiemens) indicates a high level of ionic contamination, and, a reading of 50 µmho/cm (microsiemens) indicates a low level. When the conductivity testing process substantiates a determination of a high level of contamination, the Contractor will elect to reduce the contamination to an acceptable “further use” level by adding amounts of new, clean unused abrasive, by subjecting the currently examined “in-use” lot of abrasive material with new material.

Clean, or pure water, as used in the preceding paragraphs relative to conductimetric (flushing, testing, cleaning) is defined as “deionized” water so as to preclude false test results. The water to be used is Type IV reagent water, as specified in reference (2.4).

E. Surface Profile

Surface profile recording shall be accomplished by Testex Press-O-Film Replica Tape, which will provide a reverse replica of the surface profile, or by visual determination as required to ensure proper profile. Surface will be evaluated to the required coating system.

F. Envtionmental Monitoring

(1) During grit blasting, dehumidifiers will be used as required to keep humidity acceptable limits. Testing of temperature/humidity will be conducted at commencement of shift and at mid-shift break ensure acceptable limits are maintained.

(2) Coatings shall not be applied below 40 degrees F, or when the temperature of the metal surface is less than 5 degrees F above the dew point of the ambient air. Readings are taken before, during, and upon completion of application of each coating, and recorded on ***[Insert name and number of Shipyard’s***

relevant inspection form.] Readings will be taken a minimum of every two hours and the results entered in the Humidity Reading Log maintained for the contract.

G. Paint Applications

Paint Coating System shall be in accordance with NAVSEA Standard Item #O09-32.

H. Inspection Systems

Inspections shall be conducted in accordance with NAVSEA Standard Item #009-04, and [lnsert ***name and number of relevant inspectwn form.]***

(1) Acceptability in meeting customer contractual requirements and specifications shall be prepared on ***[insert name and number of relevant test acceptance record.]*** formalizing the acceptability of surface preparation.

L Contamination Protection

Contamination Protection shall be in accord. with NAVSEA Std Item W09-06.

J. Safety

All abrasive blast operators and spray paint applicators shall wear air-supplied positive pressure full face respirators and protective clothing. Constant ventilation shall be maintained during all blasting operations in accordance with OSHA/CAL OSHA requirements.

3.1.4 Employee Qualifications

[Insert names, titles title experience levels of shipyard's Paint and Sandblast Department supetvison] personnel.]

Employees are assigned to jobs commensurate with experience-to-date, and ability. Employees in training start at clean-up jobs, masking, and other low skilled duties, and progress to the Journeyman level.

3.1.5 Inspection and Documentation

All work is inspected by a Supervisor prior to final acceptance in accordance with paragraph 3.1.3.H.

3.1.6 Acceptance and Rejection Criteria

Conduct abrasive blasting to the required specifications in effect.

3.1.7 Knowledge of Procedure Requirement

Contractor will print copies of the specifications, Process Control Procedures, and the Manufacture's application instructions for each item. These are submitted to the Supervisor prior to each job. A pre-job conference with the Supervisors and the technical representative is called if any potential problems are foreseen.

3.1.8 Hazardous Material

Material identified as hazardous waste under this PCP during the blast grit reclamation procedure will be set aside and disposed of in accordance with Federal, State, and local environmental regulations.

3.1.9 Method of Process Control Procedure (PCP) Control

The Procedure itself and on-site Supervision and Quality Assurance Inspection provides for feedback as to the continued satisfactory performance under the PCP.

3.1.10 Approval signature and title of the Sub-Contractor's Representative, as applicable, and the date of submission.

Date	Title - Department

Date	Title - Department

Date	Title - Department

4.0 ENCLOSURES

[Include all required equipment operating instructions and samples of all** relevant **shipyard forms and records.]

Additional copies of this report can be obtained from the National Shipbuilding Research Program Coordinator of the Bibliography of Publications and Microfiche Index. You can call or write to the address or phone number listed below.

NSRP Coordinator
The University of Michigan
Transportation Research Institute
Marine Systems Division
2901 Baxter Rd.
Am Arbor, MI 48109-2150
Phone: (313) 763-2465
Fax: (313) 936-1081